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Economic Impact of Environmental Regulations on the United States Copper Industry

Arthur D. Little, Inc, Cambridge, Mass

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ECONOMIC IMPACT OF ENVIRONMENTAL REGULATIONS ON THE UNITED STATES COPPER INDUSTRY

submitted to

**UNITED STATES
ENVIRONMENTAL PROTECTION AGENCY**

UNDER CONTRACT NUMBER 68-01-2842

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This report estimates, by use of an econometric model, the economic impact of environmental regulations on the United States Copper Industry. The report covers the principal air and water regulations as they affect copper mining, milling, smelting and refining. Price, employment, production and net imports are forecast over the period 1978-1987 both with and without present environmental regulations.

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FOREWORD

This study could not have been performed without the assistance and active support of many individuals, in many firms, organizations or government agencies, with whom we have had considerable interaction in the course of the entire project. We are indebted to all of them for their help.

During an extensive process of intra-agency and inter-agency review, an earlier, draft version of this report was reviewed by and received extensive comments from different parts of the United States Environmental Protection Agency (EPA), as well as from various other federal government agencies (e.g., Department of Commerce, Federal Trade Commission, Council on Wage and Price Stability, Council of Economic Advisors). The United States Bureau of Mines provided data on copper reserves and new resource developments.

We would like to acknowledge the cooperation extended by the copper industry in the performance of this study. This was particularly evident in meetings with the Industry Advisory Committee, organized during earlier phases of the project under the chairmanship of Mr. Stein I. Soelberg, then with Goldman, Sachs and Company. Further, representatives of the copper industry, through the American Mining Congress and also on an individual basis, have provided company and plant-specific information on pollution control technology and costs. We are grateful to them for their assistance. We would, in addition, like to note with appreciation the many constructive comments and criticisms received on our draft report from many individuals in the industry, including those expressed in two separate industry review meetings held in New York and Washington.

Two individuals should be singled out for special acknowledgement for their unique role in this study.

Mr. Donald A. Fink, as Technical Project Monitor, guided the study during its earlier, formative, stages and gave the study its comprehensive scope and overall methodological thrust. His personal enthusiasm and support throughout the project, both during and after his tenure as Technical Project Monitor, is very much appreciated.

Dr. Douglas Hale took over as Technical Project Monitor after Mr. Fink moved to the Federal Energy Administration (now incorporated into the new Department of Energy). The econometric simulation model of the copper industry developed and used in this study benefited from his analytical and theoretical insights. Also, we owe Dr. Hale special thanks for his ideas, comments and quests for clarity in both logic and language, during various stages of the study and report preparation, all offered or delivered with uncommon patience and understanding. All parts of this report have been the beneficiary of Dr. Hale's incisive thinking and comments. He must be held blameless, however, of the many imperfections that may still remain, regrettably, in the final version of the report presented in this volume.

PARTICIPANTS IN THIS STUDY

The principal participants in this study were as follows:

Dr. Ravindra M. Nadkarni Senior Metallurgical Engineer Project Director	Dr. Kirkor Bozdogan Senior Economist Associate Project Director

Dr. Nadkarni and Dr. Bozdogan, jointly responsible for all aspects of the study, are the principal authors of this report.

Dr. Bozdogan and Dr. Raymond S. Hartman were responsible for the development of the econometric simulation model of the copper industry used in this study. Dr. Hartman, working directly with and under the supervision of Dr. Bozdogan, had day-to-day responsibility for model design, econometric estimation and related aspects of the overall team effort. Providing technical support were, in particular, Mark Hollyer (economic research), Brian W. Smith (computer programming), and Gerald Larocque (mathematics). Dr. Glenn DeSouza provided further assistance in econometrics and computer-related work.

Donald H. Korn, assisted by Ifigenia A. Boulogiane, was responsible for financial analysis and for parts of this report devoted to the financial performance of the copper industry and individual firms.

Christopher W. Krebs assisted with research on industry structure and on environmental regulations. Dr. Krishna Parameswaran provided technical metallurgical engineering support. Lucy Tevekelian performed library research.

Virginia Hamilton, along with Elaine Coyne, provided support and secretarial services and performed all typing associated with various stages and versions of this report.

Professor Raymond F. Mikesell, W. E. Miner Professor of Economics at the University of Oregon (Eugene, Oregon) and consultant to Arthur D. Little, Inc., gave guidance particularly on the international aspects of the overall study. Mr. Charles Licht, consultant to Arthur D. Little, Inc., assisted the team on aspects of the study concerning the organization and dynamics of the secondary copper industry.

Stanley V. Margolin, senior staff member at Arthur D. Little, Inc., served as overall project reviewer.

LIST OF ABBREVIATIONS

BACT	Best Available Control Technology
BAT	Best Available Technology Economically Achievable
BPT	Best Practicable Technology Currently Available
CAA	Clean Air Act
CIPEC	Conseil Intergouvernemental des Pays Exportateurs de Cuivre (CIPEC), also known as the Council of Copper Exporting Countries
COMEX	New York Commodity Exchange
DA	Double Absorption (sulfuric acid plant)
EPA	United States Environmental Protection Agency
IBA	International Bauxite Association
LAER	Lowest Achievable Emissions Rate
LME	London Metal Exchange
MESA	Mining Enforcement and Safety Administration
NAAQS	National Ambient Air Quality Standards
NSO	Nonferrous Smelter Order
NSPS	New Source Performance Standards
OECD	Organisation for Economic Co-operation and Development
OPEC	Organization of Petroleum Exporting Countries
OSHA	United States Occupational Safety and Health Administration
PSD	Prevention of Significant Deterioration
RACT	Reasonably Available Control Technology
SA	Single Absorption (sulfuric acid plant)
SCS	Supplementary Control System
SIP	State Implementation Plan

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I. SUMMARY

A. PURPOSE AND SCOPE

This study is one of a series commissioned by the United States Environmental Protection Agency to examine in detail the combined economic impact of environmental regulations on major industries[1]. Accordingly, the objective of this study is to assess the economic impact of federal environmental regulations on the domestic copper industry. The domestic copper industry is defined here to encompass the supply of primary refined copper and secondary copper, refined or unrefined, obtained from scrap. The supply of primary refined copper includes firms engaged in the production of copper from ore deposits, involving the mining, milling, smelting and refining stages of production. Downstream semifabricating and fabricating operations are not covered in this study.

This study addresses the economic impact of regulations which implement the following federal air and water pollution abatement and control legislation[2]:

- The Clean Air Act Amendments of 1970 and 1977; and

- Federal Water Pollution Control Act Amendments of 1972.

The following legislation or regulations have not been considered in this study because they are either still being written or because their language currently provides a wide latitude for interpretation by the various administrative agencies or the courts. The degree of uncertainty associated with these potential regulations is such that estimates of compliance costs cover an extremely wide range and suggest impacts varying from negligible to extremely high. These regulations are:

- EPA's new ambient or emission standards for elements such as lead and arsenic;

- Revised effluent limitation guidelines for toxic or priority pollutants;

- Limitations on non-point sources of aqueous effluents resulting, for example, from the Safe Drinking Water Act;

- The Resource Conservation and Recovery Act;

- Auxiliary regulations or administrative interpretations governing sampling methods for sulfur dioxide, lead, etc.;

- Federal and State land management and withdrawal regulations; and

- Mining Enforcement and Safety Administration (MESA) standards.

B. APPROACH

The objective of economic impact analysis of the type reported here is to identify and assess the effects of environmental regulations on such key economic variables as prices, output, employment and international trade, among others. It is also important to consider impacts on the industry's structure and on its international competitive position. Finally, it is necessary to identify potential plant closures and assess the resulting regional or community impacts.

Environmental regulations can affect an industry and generate economic impacts in a variety of ways. Compliance with the regulations typically requires the installation of pollution abatement and control equipment and associated process changes. The resulting compliance costs, by causing an upward shift in production costs, may ultimately lead to higher prices, reduced growth in output, substitution of other materials for copper and cause related economic impact. In addition, compliance costs may influence capacity expansion, for a number of reasons (e.g., reduced profitability, slower rate of growth in output, higher imports).

Further, the regulations may directly affect capacity growth by circumscribing in technical or legal detail the conditions under which existing capacity may or may not be modified (expanded) or the conditions under which new (greenfield) capacity may be built. Alternatively, the regulations, by virtue of their evolving nature, may increase the lead times and the costs associated with new projects and, cumulatively, create increased uncertainty. The resulting increase in the riskiness of new investments may slow down capacity expansion, either simply by discouraging new investment in the industry or by raising the minimum expected rate of return on invested capital.

Consequently, economic impacts may result not only because of compliance costs but also because of direct or indirect effects on capacity expansion. In the case of the domestic copper industry, the economic impacts result from a combination (confounding) of both compliance costs and capacity effects.

Economic impacts are typically measured as deviations from a set of baseline forecasts. Baseline forecasts are estimates of the values that all pertinent variables would take, over a period of time, in the absence of environmental regulations (or at least in substantial absence of environmental regulations). Under the assumption that the regulations are implemented, the same variables would take new values, over the same time period, because of increased costs of production due to compliance and because of the direct and indirect effects of the regulations on capacity growth. The differences between the two sets of results are attributed to the environmental regulations and define the economic impacts.

For impact analysis in this study, a computerized econometric simulation model of the United States copper industry has been developed and used. Figure I-1 presents a simplified flow diagram of the structure of this model. The model is designed, estimated and programmed to simulate the industry's growth and evolution annually through 1987 under baseline conditions as well as under alternative policy scenarios. The model considers, within an interdependent framework, such variables as demand (paying attention to substitution from other materials such as aluminum), costs of production facing the producers, prices, investment and international trade. Costs of production are directly factored into the model through engineering cost functions so that technological developments as well as environmental factors affecting the industry can be readily assessed. Although the overall model specifically deals with both the primary producers and with the secondary copper industry (and the interaction between the two sectors), its major focus is on the primary producers. The model provides a unified analytical framework capturing quantitatively the pertinent interrelationships, to deal effectively with the measurement of impacts since environmental regulations set into motion an essentially simultaneous (interdependent) adjustment process in supply (costs), demand, prices and other variables.

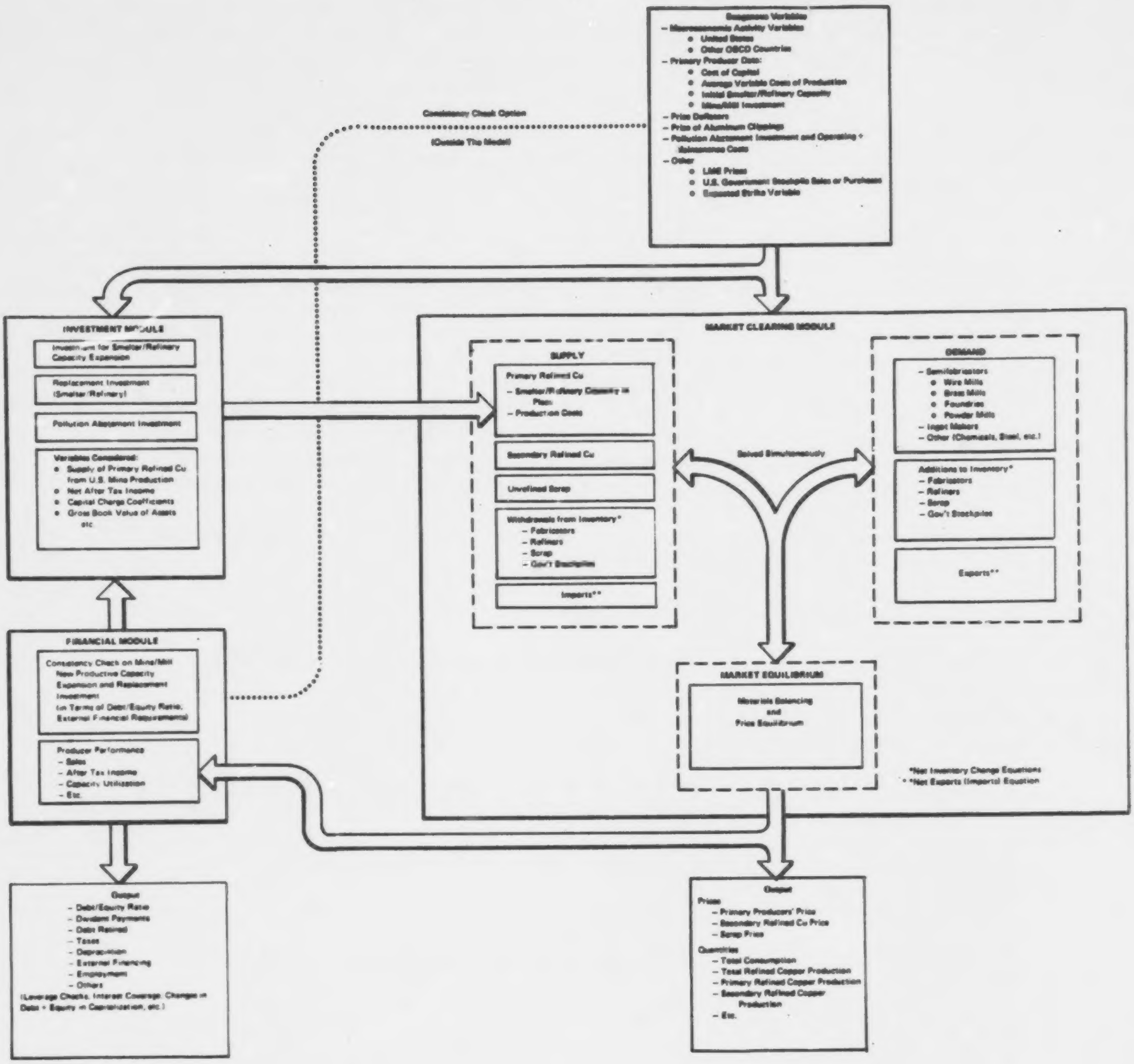
The model's output includes, among others, the following major variables which are jointly determined:

- total consumption of refined copper and its equivalent;
- changes in inventory stocks (additions, reductions) of primary producers, semifabricators, and secondary refiners;
- net international trade (net exports, net imports);
- production of primary refined copper by the domestic primary producers;
- production of secondary refined copper from scrap;
- production of scrap copper which is used directly;
- price of primary refined copper (domestic producers' price);
- price of secondary refined copper;
- price of copper scrap.

The model was used to develop annual forecasts over the period 1974-1987, which defines the impact analysis period, under baseline conditions as well as under alternative environmental scenarios.

FIGURE I-1

SIMPLIFIED FLOW DIAGRAM OF THE ECONOMETRIC SIMULATION MODEL OF THE UNITED STATES COPPER INDUSTRY


Exogenous Variables
– Macroeconomic Activity Variables
• United States
• Other OECD Countries
– Primary Producer Data:
• Cost of Capital
• Average Variable Costs of Production
• Initial Smelter/Refinery Capacity
• Mine/Mill Investment
– Price Deflators
– Price of Aluminum Clippings
– Pollution Abatement Investment and Operating + Maintenance Costs
– Other
• LME Prices
• U.S. Government Stockpile Sales or Purchases
• Expected Strike Variable
Consistency Check Option
(Outside The Model)
INVESTMENT MODULE
Investment for Smelter/Refinery Capacity Expansion
Replacement Investment (Smelter/Refinery)
Pollution Abatement Investment
Variables Considered:
• Supply of Primary Refined Cu from U.S. Mine Production
• Net After Tax Income
• Capital Charge Coefficients
• Gross Book Value of Assets
etc.
MARKET CLEARING MODULE
SUPPLY
Primary Refined Cu
– Smelter/Refinery Capacity in Place
– Production Costs
Secondary Refined Cu
Unrefined Scrap
Withdrawals from Inventory*
– Fabricators
– Refiners
– Scrap
– Gov't Stockpiles
Imports**
Solved Simultaneously
DEMAND
– Semifabricators
• Wire Mills
• Brass Mills
• Foundries
• Powder Mills
– Ingot Makers
– Other (Chemicals, Steel, etc.)
Additions to Inventory*
– Fabricators
– Refiners
– Scrap
– Gov't Stockpiles
Exports**
FINANCIAL MODULE
Consistency Check on Mine/Mill New Productive Capacity Expansion and Replacement Investment (in Terms of Debt/Equity Ratio, External Financial Requirements)
Producer Performance
– Sales
– After Tax Income
– Capacity Utilization
– Etc.
MARKET EQUILIBRIUM
Materials Balancing and Price Equilibrium
*Net Inventory Change Equations
**Net Exports (Imports) Equation
Output
– Debt/Equity Ratio
– Dividend Payments
– Debt Retired
– Taxes
– Depreciation
– External Financing
– Employment
– Others
(Leverage Checks, Interest Coverage, Changes in Debt + Equity in Capitalization, etc.)
Output
Prices
– Primary Producers' Price
– Secondary Refined Cu Price
– Scrap Price
Quantities
– Total Consumption
– Total Refined Copper Production
– Primary Refined Copper Production
– Secondary Refined Copper Production
– Etc.

C. ENVIRONMENTAL REGULATIONS

1. Sources of Pollution

All four stages of primary copper production (mining, milling, smelting, and refining) are affected by Federal environmental regulations. Mining and milling are affected mainly by water and solid waste regulations, smelting by air regulations, and refining by water regulations. Of these, the air pollution control regulations for copper smelters are currently the most significant.

The conventional smelting of copper sulfide concentrates typically involves three steps: roasting, smelting and converting. Of these, the roasting step is optional. Roasted concentrates (calcines) or concentrates as received can be smelted in reverberatory furnaces (reverbs). The smelting process generates gas streams containing a large amount of sulfur dioxide at each process unit (i.e., roaster, reverb, or converter). In addition, the converting operation generates a small amount of sulfur dioxide which is very dilute and difficult to capture ("fugitives").

The distribution of sulfur among the gas streams emitted by these sources, expressed as percent of total sulfur contained in the concentrates entering the smelter, and the characteristics of these gas streams, are as follows:

Source	Emission Stream Characteristics	Sulfur distribution (% of sulfur contained in concentrates entering the smelter)	
		Calcine Smelting	Concentrate Smelting
Roaster	strong[3]-continuous	20	-
Reverb	weak[3]-continuous	25	40
Converter	strong[3]-intermittent	50	55
Fugitives	very weak[3]-intermittent	5	5

The predominant technique used to control emissions at a smelter is through the construction of sulfuric acid plants, whereby the sulfur dioxide (SO_2) is converted to sulfuric acid.

Sulfuric acid plants can utilize only the strong sulfur dioxide streams. Thus, the use of this conventional technique can capture about 50-70 percent of the sulfur in the smelter feed materials. The weak SO_2 stream from the reverb and the roasters, after suitable treatment for the removal of particulate matter, are emitted to the atmosphere using tall stacks. The fugitives are emitted close to the ground.

2. Air Pollution Control Regulations

The Clean Air Act Amendments of 1970 and 1977 establish four principles that are particularly relevant to air pollution control in copper smelting. They are the following:

- The Amendments require that National Ambient Air Quality Standards (NAAQS) be met at all times by the use of permanent emissions reduction technology. Intermittent control systems based on dispersion by any means, most notably by the use of tall smoke stacks, and production curtailment to reduce emissions under adverse meteorological conditions (i.e., Supplementary Control Systems or SCS) are not acceptable means of achieving ambient air quality standards. These requirements lead to the establishment of an "ultimate emissions limit", discussed below, which must be achieved no later than January 1, 1988.
- All new sources must use Best Available Control Technology (BACT) for permanent reduction of emissions. This requirement results in New Source Performance Standards (NSPS) for new sources or for reconstructed and modified existing sources.
- The Amendments require that smelting activity cannot lead to significant deterioration of existing air quality in regions which are cleaner than the ambient standards. For a particular location, these requirements define the extent to which new smelting activity can increase ambient concentrations of pollutants.
- In areas which have not attained ambient standards, the Amendments require that reasonable progress be made towards the achievement of National Ambient Air Quality Standards. This results in a series of preconditions which must be met before modifying an existing emissions source. Basically, total emissions after modification have to be lower than prior emissions (i.e., "emissions offsets") by using emission control technology capable of the "Lowest Achievable Emissions Rate" (LAER). Typically, existing smelters would be designated to be in nonattainment areas because they will not be achieving the ultimate emissions limit. Any modification of an existing smelter would therefore be subject to the requirements noted above and would have to be consistent with the attainment of the ultimate emissions limit by 1988.

As a result, copper smelters are potentially subject to several types of limitations on the emission of sulfur dioxide (SO_2) into the atmosphere. These emissions limitations differ in terms of their degree of stringency, method of calculation and applicability (i.e., whether they apply to the smelter as a whole or to individual pieces of equipment). They are the ultimate emissions limit, Lowest Achievable Emissions Rate (LAER), Best Available Control Technology (BACT) and Reasonably Available Control Technology (RACT). In addition, New Source Performance Standards (NSPS) apply to major pieces of process equipment.

For each smelter an ultimate emissions limitation is established at a level sufficient to ensure that NAAQS are met at all times without the use of dispersion techniques or production curtailment. This ultimate emissions limit, which is to be calculated assuming stack heights of two-and-one-half times building height or less for stacks built after 1970, is computed through the use of diffusion modeling and is dependent on the allowable stack height, the weather and topography in the vicinity of the smelter and smelter size. The ultimate emissions limit generally requires the capture of over 90 percent of the sulfur in the input (feed) materials entering the smelter.

The other emissions limits are technology-related and depend on the processing equipment used at a particular smelter. In increasing order of stringency, they are RACT, BACT and LAER.

- RACT is usually defined as control of all strong sulfur dioxide gases (approximately 4-5 percent SO_2) by a double absorption acid plant, if these gases were not being treated, or control by a single absorption plant if such a system were already being utilized. RACT at existing smelters can achieve 50-70 percent capture of the sulfur in the input (feed) materials.

- BACT and NSPS are usually the same. (NSPS can be less stringent than BACT because of delays in NSPS revision). NSPS require that gases from any new, reconstructed or modified smelting furnace, roaster or converter be treated in a pollution control system equivalent to a double absorption acid plant which removes 99.6 percent of the sulfur dioxide in the gas stream. BACT/NSPS applied to non-reverb smelting can achieve over 90 percent control.

- LAER could achieve additional pollution control beyond BACT via the control of fugitive emissions, weak gas scrubbing, etc.

Under the Clean Air Act Amendments of 1977 an existing smelter not meeting the ultimate emissions limit can continue to operate under a nonferrous smelter order (NSO). The NSO is essentially a five-year variance, renewable once, which allows a smelter to operate using Reasonably Available Control Technology (RACT) or as much control equipment as it can afford, together with tall stacks and SCS. Only those copper smelters that are technically or economically unable to meet the ultimate emissions limit for sulfur dioxide are eligible to operate under an NSO. Upon termination of the NSO, the smelter must either be achieving the ultimate emission limit or it must close down. As a condition of operating under an NSO, the smelter must install as much pollution control equipment as it can afford, must continue R&D on emissions reduction technology, and must achieve ambient air quality standards.

D. FINDINGS

1. Direct Impact of Pollution Control Regulations on Capacity Growth

The basic conclusion emerging from an analysis of the historical pattern of smelter capacity expansion is that the copper industry has traditionally preferred incremental expansion at existing sites, rather than the construction of new (greenfield) smelters. The lead time required for planning, engineering, construction, shake-down and start-up for small expansions at existing sites is about two-to-three years while that for new (greenfield) smelters is about five-to-seven years.

The presently promulgated environmental regulations, summarized above, affect capacity expansion of the domestic copper industry in the following fashion. First, they do not allow (or, effectively prohibit) small smelter expansions of the type used traditionally by the industry. Second, while there are some uncertainties, the regulations appear to allow the construction of NSPS caliber (or better) smelters in new locations and also in existing smelter locations. However, because of the lead time requirements, major new capacity of this type is not likely to come on-stream before 1985. Finally, the reverb based smelters will have to undergo major alterations to non-reverb technology by 1988 or they would have to shut down. Consequently, the currently promulgated environmental regulations will effectively constrain domestic capacity growth until 1985 and would require major expenditures for capacity maintenance between 1983 and 1988. In the interim, minor increases in capacity are expected for hydrometallurgical processing of oxides and expansion at non-reverb smelters.

The prospects for capacity expansion at the mining, milling and refining stages of production are not independent of the growth or contraction in smelting capacity. That is, smelting capacity essentially represents the "bottleneck" in primary refined copper production. Hence, the foregoing findings strongly suggest that the supply of refined copper domestically will be constrained over the next decade because of the constraints on domestic smelter capacity growth.

The domestic copper industry faces a variety of theoretically plausible paths for smelter capacity expansion, within the constraints or bounds circumscribed by the regulations, and subject also to economic constraints. These paths cover the following possibilities: (1) all existing smelters will be in compliance with the requirements of the 1977 Amendments by January 1, 1988; (2) some smelters will choose to shut down instead of complying with the ultimate emission requirements; (3) one or more greenfield smelters will come on-stream during the period 1985-1987; (4) additional leach-electrowinning capacity will be brought on-stream during 1978-1987; and (5) four non-reverberatory smelters that are at or close to compliance with the New Source Performance Standards (Inspiration, Hidalgo, Anaconda, and Garfield) will be allowed to increase their capacity without installing incremental pollution control beyond NSPS.

Of the various permutations and combinations of these paths, two combinations have been selected as the most plausible for the purpose of economic impact analysis. These scenarios, labeled "Constrained Capacity" and "Reduced Capacity", are defined as follows:

- Constrained Capacity: This scenario assumes that none of the existing smelters will shut down; all smelters currently employing reverberatory furnaces will make progress towards compliance by January 1, 1988; that no new (greenfield) smelter capacity will be coming on-stream during this period; and that only marginal electrowinning capacity is expected to be introduced over the five-year period 1983-1987.

- Reduced Capacity: This scenario, which is the more severe in terms of capacity expansion, assumes that three smelters (Phelps Dodge-Douglas, Kennecott-McGill, and Asarco-Tacoma or an equivalent smelter) will close down in 1983, for various reasons. These three smelters have a combined capacity of 268,000 annual short tons of refined copper equivalent. As under the Constrained Capacity scenario, no new (greenfield) smelter capacity will be coming on-stream during this period, and only marginal electrowinning capacity is expected to be introduced during the five-year period 1983-1987.

2. Compliance Costs

Estimated pollution control capital expenditures, as well as operating and maintenance costs over the period 1974-1987, under the two basic environmental scenarios just described, are given in Table I-1.

These estimates assume that there will be no fundamental change in the relative cost and nature of pollution control technology between now and 1988. The costs shown are for (1) the control of strong streams using acid plants, (2) the control of fugitive emissions by improved collection and the use of tall stacks for dispersal; and (3) the conversion of reverberatory smelters to non-reverberatory smelting by 1988.

TABLE I-1

ESTIMATES OF POLLUTION ABATEMENT AND CONTROL EXPENDITURES BY THE UNITED STATES COPPER INDUSTRY[a], 1974-1987

(In millions of 1974 dollars)

Year	CONSTRAINED CAPACITY					REDUCED CAPACITY				
	Capita. Expenditures[b]			Operating and Maintenance Costs[e]	TOTAL	Capital Expenditures[b]			Operating and Maintenance Costs	TOTAL
	Non-reverberatory Related Capital Expenditures	Reverberatory Conversion Investment[c]	Total			Non-reverberatory Related Capital Expenditures	Reverberatory Conversion Investment[d]	Total		
1974	226.0	-	226.0	57.4	283.4	226.0	-	226.0	57.4	283.4
1975	240.8	-	240.8	49.3	290.1	240.8	-	240.8	49.3	290.1
1976	156.0	-	156.0	48.8	204.8	156.0	-	156.0	48.8	204.8
1977	90.0	-	90.0	42.3	132.3	90.0	-	90.0	42.3	132.3
1978	60.0	-	60.0	98.0	158.0	60.0	-	60.0	98.0	158.0
1979	40.0	-	40.0	88.2	128.2	40.0	-	40.0	88.2	128.2
1980	40.0	-	40.0	89.5	129.5	40.0	-	40.0	89.5	129.5
1981	40.0	-	40.0	89.8	129.8	40.0	-	40.0	89.3	129.8
1982	40.0	-	40.0	89.6	129.6	40.0	-	40.0	89.9	129.9
1983	40.0	156.5	196.5	90.0	286.5	40.0	126.7	166.7	78.6	245.3
1984	40.0	156.5	196.5	89.8	286.3	40.0	126.7	166.7	78.4	245.1
1985	40.0	156.5	196.6	90.1	286.6	40.0	126.7	166.7	78.5	245.2
1986	40.0	156.5	196.5	90.2	286.7	40.0	126.7	166.7	78.5	245.2
1987	-	156.5	196.5	90.0	246.5	-	126.7	126.7	78.4	205.1
1974-1987	1,092.8	782.5	1,875.3	1,103.0	2,978.3	1,092.8	633.5	1,726.3	1,045.6	2,771.9
1978-1987	380.0	782.5	1,162.5	905.2	2,067.7	380.0	633.5	1,013.5	847.8	1,861.3

NOTES: For all footnotes, refer to Table XII-2 in the report.

SOURCE: Arthur D. Little, Inc., estimates.

The cumulative capital investment is estimated to range between $1.7 billion (under Reduced Capacity) and $1.9 billion (under Constrained Capacity) in 1974 dollars over the period 1974-1987. Cumulative direct operating and maintenance cost is estimated to range between $1.0 billion (Reduced Capacity) and $1.1 billion (Constrained Capacity) in 1974 dollars over the same period. Total cumulative spending by the industry for pollution control over this period, including both capital and direct operating costs, is hence estimated to range between $2.8 billion and $3.0 billion in 1974 dollars.

Four points should be noted. First, these estimates exclude the industry's spending for pollution control over the period 1970-1973. Cumulative capital investment for pollution control over this period is estimated at $402 million. Second, roughly one-third of the total estimated cumulative pollution control expenditures over the period 1974-1987 have already been incurred (through 1977). Third, cumulative investment for reverberatory conversion required under the Clean Air Act Amendments of 1977, estimated at $783 million (in 1974 dollars) accounts for over 60 percent of total capital expenditures over the 1978-1987 period under the two environmental scenarios. Fourth, the expenditure levels given here will not necessarily be sufficient for the smelters to meet the ultimate emissions limit in all cases.

3. Baseline Forecasts

Baseline forecasts provide a point of reference from which comparisons can be made in order to gauge the relative and absolute magnitude of the economic impacts. A given set of baseline forecasts represent a fairly reasonable approximation of a generally plausible future picture of the world which can be used as a benchmark for comparison. For economic impact analysis, emphasis is generally put not on absolute differences from baseline conditions but on relative (percentage) differences. To safeguard against any systematic bias in the measurement of impacts, many alternative sets of experimental baseline forecasts were developed under alternative macroeconomic growth and other assumptions before deciding upon the baseline forecasts shown in Table I-2.

The macroeconomic growth scenario that is assumed generally reflects moderate and steady growth in overall economic activity in the United States. The European economies, meanwhile, are expected to follow a slightly slower recovery and growth path, lagging the United States.

The baseline forecasts assume the existence of National Ambient Air Quality Standards (NAAQS) but assume the absence of additional restrictions regarding how such standards might be achieved. This means, in other words, nominal industry compliance with NAAQS, through minimal permanent control and extensive use of SCS, but no constraints on the modes of capacity growth. As a related matter, the baseline costs for new capacity assume that this capacity would be built with acid plants for controlling strong streams, but without other pollution control measures. Pollution control costs are hence treated as part of the cost of production.

The impact analysis period was defined as the 1974-1987 time span, where 1974, the base year in the analysis, is also the start of the impact analysis period. The year 1987 represents the terminal year of the second Nonferrous Smelter Order (NSO) period specified under the Clean Air Act Amendments of 1977.

4. Summary of Economic Impacts

The combined effects of both capacity constraints under the "Constrained Capacity" and "Reduced Capacity" scenarios and the associated pollution control expenditures result in the economic impacts tabulated in Table I-2 and summarized below.

a. Impact on Prices

The price impacts of the presently promulgated environmental regulations reflect the combined influences of both compliance costs and constraints on capacity growth. Under Constrained Capacity, prices are 23.3 percent higher in 1985 and 29.4 percent higher in 1987 than those prevailing under baseline conditions. Under Reduced Capacity, real prices are higher than the baseline prices by 32.8 percent in 1985 and 38.7 percent in 1987. The forecasts of prices under the Constrained Capacity and Reduced Capacity scenarios should be interpreted as the price levels that would be expected to result from environmental regulations in the absence of a massive infusion of imports into the United States. Imports would be much higher if the rest-of-the-world (i.e., London Metal Exchange--LME) copper prices stay lower than the levels assumed under baseline conditions. The baseline conditions already show a persistent increase in the level of imports, a significant reversal of past trends.

b. Impact on Production

The impact on domestic primary refined copper production closely parallels the impact on copper prices, but in the opposite direction, resulting in a decrease in output. The full force of the production impact is felt in 1987, when domestic production falls 24.9 percent below the baseline forecast under Constrained Capacity and 32.9 percent under Reduced Capacity.

TABLE I-2

ECONOMIC IMPACTS UNDER ALTERNATIVE ENVIRONMENTAL SCENARIOS AND CORRESPONDING COMPLIANCE COSTS ON THE UNITED STATES COPPER INDUSTRY, 1974-1987: SUMMARY OF SELECTED RESULTS

(all dollar figures in 1974 prices; quantities are in thousands of short tons)

IMPACT VARIABLE/SCENARIO	1974	1977	1979	1981	1983	1985	1987
Primary Refined Copper Prices							
Baseline	77.2	56.4	68.9	72.9	76.6	74.8	77.2
Constrained Capacity	77.3	59.4	73.5	80.5	88.7	92.2	99.9
Reduced Capacity	77.3	59.4	73.5	80.5	96.6	99.3	107.1
% Differences from Baseline							
Constrained Capacity	0.1	5.3	6.7	10.4	15.8	23.3	29.4
Reduced Capacity	0.1	5.3	6.7	10.4	26.1	32.8	38.7
Primary Refined Copper Production[a]							
Baseline	1792.7	2060.7	2191.6	2314.7	2477.5	2688.4	2897.3
Constrained Capacity	1790.6	1971.2	2039.6	2072.4	2095.6	2136.6	2175.5
Reduced Capacity	1790.6	1971.2	2039.6	2072.4	1867.3	1905.5	1943.0
% Difference from Baseline							
Constrained Capacity	-0.1	-4.3	-6.9	-10.5	-15.4	-20.5	-24.9
Reduced Capacity	-0.1	-4.3	-6.9	-10.5	-24.6	-29.1	-32.9
Net Imports[b]							
Baseline	167.1	239.6	274.3	361.5	356.0	513.8	571.2
Constrained Capacity	167.4	251.5	292.5	391.8	404.0	583.0	661.1
Reduced Capacity	167.4	251.5	292.5	391.8	435.2	611.2	689.6
% Differences from Baseline							
Constrained Capacity	0.2	4.9	6.6	8.4	13.5	13.5	15.7
Reduced Capacity	0.2	4.9	6.6	8.4	22.2	18.9	20.7
Total Consumption[c]							
Baseline	3397.8	3455.1	3792.4	4027.3	4221.8	4567.9	4864.3
Constrained Capacity	3396.9	3405.9	3708.6	3899.7	4019.3	4274.1	4474.1
Reduced Capacity	3396.9	3405.9	3708.6	3899.7	3917.0	4147.2	4345.2
% Differences from Baseline							
Constrained Capacity	-0.02	-1.4	-2.2	-3.2	-4.8	-6.4	-8.0
Reduced Capacity	-0.02	-1.4	-2.2	-3.2	-7.2	-9.2	-10.7
Employment[d]							
Baseline	62,953	58,051	64,886	68,530	73,350	79,595	85,780
Constrained Capacity	62,879	55,530	60,386	61,357	62,044	63,258	64,410
Reduced Capacity	62,879	55,530	60,386	61,357	55,285	56.416	57,526
% Differences from Baseline							
Constrained Capacity	-0.1	-4.3	-6.9	-10.5	-15.4	-20.5	-24.9
Reduced Capacity	-0.1	-4.3	-6.9	-10.5	-24.6	-29.1	-32.9

NOTES: [a] Domestic production of refined copper by primary producers, from all sources (domestically mined copper, imported ore/concentrate/blister/scrap, domestically generated unalloyed scrap); although it contains some secondary refined copper, it is exclusive of secondary refined output produced by secondary refiners.

[b] Net of exports.

[c] Includes primary and secondary refined copper, directly consumed scrap and imports.

[d] Total full-time equivalent employment (number of persons) including mining and milling, smelting and refining employment at all domestic primary producers facilities; employment by secondary smelters/refiners are excluded.

SOURCE: COPMOD I (i.e., the acronym used for the Econometric Simulation and Impact Analysis Model of the U.S. Copper Industry developed as part of this project; refer to Chapter XI for a general description and to the Technical Appendix accompanying this volume for a detailed description of this model).

c. Impact on International Trade

The overall pattern emerging from the model forecasts under baseline conditions is that net imports show a persistent increase over time, which represent a reversal of past trends. Under Constrained Capacity, net imports in the 1980s are generally 13-15 percent above baseline levels. Under Reduced Capacity, net imports become 20.7 percent higher than the baseline level by 1987. Again, imports would be much higher if the LME copper prices continue to remain depressed.

d. Impact on Consumption

The drop in total consumption below baseline levels is expected to reach 8.0 percent under Constrained Capacity and 10.7 percent under Reduced Capacity by 1987. The drop in total consumption is not as large as in domestic refined copper production, since demand for copper remains relatively inelastic and consumers make greater use of secondary refined copper, scrap, and imports, while restraining their consumption somewhat because of higher prices.

e. Impact on Employment

The impact on industry-wide employment at all stages of production (mining through refining), under both the Constrained Capacity and the Reduced Capacity scenarios, is expected to be felt sharply in terms of curtailing employment growth that would otherwise be expected to occur under baseline conditions. Basically, under the particular baseline forecasts used, Constrained Capacity would prevent about 21,000 full-time equivalent jobs and Reduced Capacity nearly 28,000 jobs by 1987, which respectively represent 24.9 percent and 32.9 percent less employment than under baseline conditions. It should be noted that no significant compensating employment growth in the secondary copper industry is expected. Likewise, employment growth at smelters due to pollution abatement would be relatively small.

The employment impacts under Constrained Capacity do not reflect layoffs but represent lower potential growth in a few Western states (e.g., Arizona, Utah, New Mexico, Montana, Nevada) where domestic copper mining, milling, and smelting operations are largely concentrated. The employment impacts under Reduced Capacity, with the exception of potential layoffs at the three smelters assumed to close down under this scenario (Kennecott-McGill, Phelps Dodge-Douglas, and Asarco-Tacoma or an equivalent smelter), would also basically reflect foregone employment growth.

f. Community Impacts

If Kennecott-McGill (Nevada) and Phelps Dodge-Douglas (Arizona) smelters actually do close down, as hypothesized under the Reduced Capacity Scenario, the impact on these two isolated communities would be severe. If, similarly, Asarco-Tacoma is closed down, as further hypothesized under the Reduced Capacity Scenario, the local impact would be quite significant.

These three smelters together employ about 3,100 persons (McGill, 1,480; Douglas, 610; Tacoma, 1,000). Th[illegible]ill smelter is virtually the only source of employment in that community and accounts for over half the jobs in White Pine County, which contains McGill. Similarly, the Douglas smelter is a major employer, providing about 15 percent of total jobs in that community. Finally, the Tacoma smelter has remained, over many decades, a significant source of employment in Tacoma, even though the smelter currently contributes just over one percent of all jobs in Greater Tacoma (Pierce County).

g. Additional Impacts

These main economic impact results are supplemented by the following related findings:

- Smelter capacity utilization rates will remain extremely high during the next ten years, becoming progressively higher under the Constrained Capacity and Reduced Capacity Scenarios.

- Not much relief in the form of significantly increased supply of secondary copper is expected over the next ten years under either environmental scenario. Secondary copper prices, however, rise above baseline levels; by 1987 scrap copper prices will rise by as much as 27.0 percent above baseline forecasts under Constrained Capacity and 35.4 percent under Reduced Capacity, in view of the constraint on domestic smelter capacity growth and the relatively inelastic supply of secondary copper. Meanwhile the demand for copper is expected to shift upward secularly with the rise in industrial and investment activity.

h. Sensitivity Analysis

A sensitivity analysis was conducted to see how the impact results reported above might change under a somewhat different specification of the environmental/industry capacity growth scenarios. Specifically, the Constrained Capacity and Reduced Capacity scenarios were modified, by assuming alternative modes of smelter capacity expansion (including new smelters) and correspondingly introducing new estimates of compliance costs. Five different tests were performed. An examination of the sensitivity analysis results generally indicates that the severity of the impacts reported earlier, falling especially over the period

1983-1987, would remain broadly unchanged. Overall, the impacts are lessened when new capacity is assumed to come on-stream during this period under the various sensitivity tests. Everything considered, the lowest deviations from the baseline results appear to be those associated with a modified version of the Constrained Capacity scenario, which allows for new smelters to come on-stream in 1985 and 1987.

The baseline forecasts underlying the impact analysis and sensitivity tests reported above assume steady economic growth both in the United States and in other industrial countries. They further assume a gradual improvement in LME copper prices, in line with the expected macroeconomic growth conditions worldwide, along with expected costs of production abroad as well as expected mine capacity expansion in key copper exporting countries. However, worldwide economic recovery and growth might continue to be quite slow, and the LME copper prices might continue to remain at relatively low levels (i.e., significantly below assumed baseline levels). Then an unavoidable consequence of such a development would be a substantial rise in imports into the United States, low domestic copper prices resulting from increased foreign competition and a relatively depressed domestic copper industry. Under such circumstances, the impact of the environmental regulations on the domestic copper industry could prove extremely serious.

5. Broader Implications of Environmental Regulations and Related Issues

The environmental regulations and the impact results discussed earlier have broader implications and raise certain issues which deserve emphasis. These pertain to the regulatory environment, the growth of the domestic copper industry and the international economic implications.

a. Regulatory Environment

Environmental regulations not only lead to increased production costs due to the cost of compliance, but also cause uncertainty because of their evolving nature. For the copper industry, a major source of uncertainty in the future relates to the fugitive emissions problem (i.e., the magnitude of the fugitive emissions, the degree to which they might contribute to the violation of ambient standards even in the vicinity of smelters using modern, "exemplary" technology and the means which might be used to alleviate this problem). From a planning standpoint, the problem of uncertainty would increase the degree of risk associated with a new project, thus making the industry more cautious and increasing both the lead times and the costs required for adding new capacity. This, combined with the cumulative and sometimes conflicting nature of the regulations, may further create a broader set of unintended consequences, for example, by effectively curtailing expansion of domestic productive capacity. Moreover, the existence of many regulatory agencies affecting a given industry, with little or no coordination among them (in the apparent absence of any legal requirement for them to coordinate their activities), may well compound the unintended and unforeseen effects of their actions. The situation may get more complex in the future if the present pattern of regulation of industry by Federal Government agencies continues.

b. General Issues Pertaining to the Future of the Domestic Copper Industry

The following general conclusions are suggested from the foregoing discussion and findings:

- Growth of the domestic copper industry: The constraint on domestic smelter capacity growth imposed by the presently promulgated federal environmental regulations, the continuing future uncertainty regarding new regulations and the way they will be enforced will quite likely slow down domestic smelter capacity expansion and new resource development generally.
- Technological and energy implications: The federal regulations affecting the copper industry in part represent an apparent desire to force technological change away from reverb-based technology towards new smelting technology more amenable to sulfur dioxide emissions control via the use of sulfuric acid plants. Although this new smelting technology is more energy efficient than reverb-based technology as far as smelting is concerned, the higher degree of pollution control offsets this advantage.
- The threat of substitution from aluminum: Aluminum prices could increase relative to copper prices, because of the actions of the major bauxite producing countries (e.g., increased taxes, cartelization, etc.) or because of higher energy costs. This may slow down the substitution of aluminum for copper but not necessarily stop it, especially because domestic copper prices would also rise because of compliance costs and constraints on domestic capacity growth.

c. International Economic Implications

The capacity constraints and costs of compliance resulting from environmental regulations may have significant international economic implications beyond those noted above pertaining to international trade effects. These can be summarized as follows:

- Effects on the international competitive position of the domestic copper industry: While the foregoing findings suggest that the international competitive position of the domestic copper industry will deteriorate, there may be mitigating factors which may also increase the costs of foreign production. Among these factors can be cited differential impacts of energy price increases, expected high rates of inflation not offset by exchange rate adjustments, high infrastructure investment requirements, generally lower labor productivity, and a growing set of requirements by international financing institutions (e.g., the World Bank) for pollution control at new projects.

- Effects on the international investment behavior of the domestic copper producers: Industry sources state that differences among various countries in terms of pollution control costs alone are likely to prove quite insignificant, in their decisions regarding new investments abroad, compared with the large number of uncertain factors associated with foreign investment in most developing countries. Further, while political risks abroad are generally assigned greater weight than environmental risks faced at home, there is a growing climate of opinion that political risks abroad are controllable through international financing, joint ventures, majority ownership in the host country, and other means. Accordingly, there appears to be emerging the perception that the cycle of expropriation abroad is at an end, whereas the end of environmental regulations in the United States is nowhere in sight. Hence, new investment is likely to be exported abroad to areas which are considered less risky politically. The recent growth in copper production capacity in Canada takes on new significance when viewed in this light. The Canadian copper industry, which will be a major beneficiary of the capacity constraint in the United States, is expected to emerge as a major exporter of copper to the United States.

- Implications for the structure of the copper industry: During the postwar period, the copper industry progressively became geographically more diverse worldwide and less concentrated. The capacity constraints emanating from environmental regulations domestically and the poor economic conditions facing the industry internationally are likely to slow down or delay the entry of new firms. This, combined with the recent emergence of CIPEC, may reverse the postwar trend.

- Implications for cartelization and international commodity agreements: CIPEC, patterned after OPEC, the oil "cartel", has yet to evolve a mechanism to control prices or, far short of that, to stabilize prices through an international buffer stock arrangement.

In the normal course of events in the future, the likelihood of the emergence of a CIPEC cartel would not appear to be high. Nevertheless, the likelihood that an expanded CIPEC will be able to exercise some influence or even control over the world price of copper in the medium-term future cannot be ruled out. Such a development could occur especially in the event of strong worldwide economic recovery, and might be aided, to some degree, by the constraint on smelter capacity growth in the United States. Strong worldwide economic recovery and growth would help improve the payments deficits of the CIPEC member countries and would, hence, ease the pressure on them for competitive pricing among themselves to obtain badly needed foreign exchange. In the longer-run, however, CIPEC would not appear likely to influence the course of world copper prices. Collusive control of copper prices, at higher disequilibrium prices, would soon invite increased primary copper supply from non-CIPEC sources, bring about some increase in the supply of secondary copper and hasten the substitution of other materials for copper. This would readily undermine efforts at collusive control of world copper prices over the long-run. Hence, for CIPEC, the ability to influence prices over a relatively short period would have to be weighed against longer-term earnings, in view of the generally self-correcting forces quite strongly present in the world copper market.

E. OVERVIEW OF THE COPPER INDUSTRY

1. Introduction

The United States is the leading producer and consumer of copper in the world, accounting for about one-fifth of total world refined copper production, consumption and reserves. Except for certain periods in the past coinciding with military developments or unusually high rates of economic growth, the United States has been nearly self-sufficient in copper. In the past two years, however, imports of foreign refined copper have increased significantly, reaching 21 percent of total domestic refined copper consumption in 1976 and roughly 25 percent in 1977.

With their sales from refined copper at about $2.5-3.0 billion, the domestic primary copper producers employ over 60,000 people in mining through refining, concentrated in such key copper producing states as Arizona, Utah, New Mexico, Montana and Nevada.

2. Sources of Copper and Production Technology

There are three major sources of copper: sulfide copper ores, oxide copper ores and scrap. Of these, the sulfide resources are the most important and we expect them to continue to play a dominant role in meeting demand in the foreseeable future.

Production of refined copper in the United States from all sources is shown in Figure I-2. Domestically mined copper accounts for a major share of the total copper supply stream. In addition, copper recovered from scrap represents an important source of copper.

The production of primary (mined) copper is based mainly on the exploitation of low grade sulfide mineral deposits on a large scale and involves four stages of processing:

- mining--where ore containing approximately 0.4-2 percent copper is mined;
- beneficiation (or milling)--where the copper-containing minerals are separated from waste rock to produce a concentrate containing about 25 percent copper;
- smelting--where concentrates that contain about 25 percent copper are smelted to produce "blister" copper of 98 percent purity;
- refining--where blister copper is refined electrolytically to produce cathode copper of 99.9 percent purity. Subsequently, cathode copper is melted and cast into various shapes for fabrication.

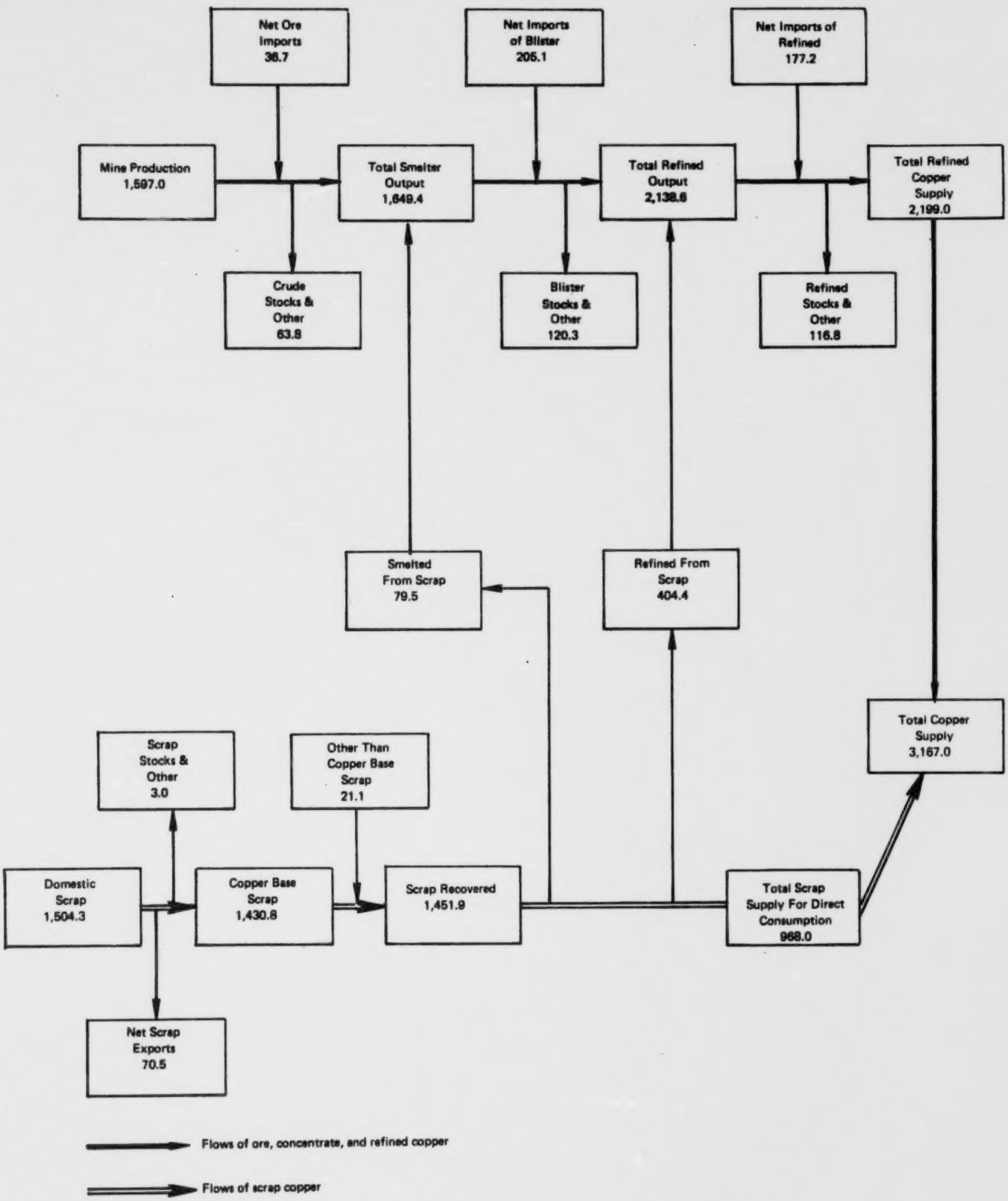
About 98 percent of the domestic mine production of copper comes from ores mined primarily for their copper content, the remainder is recovered from complex or mixed base-metal ores. The copper ores also are the source of significant quantities of by-products and co-products such as gold, silver, molybdenum, nickel, platinum, selenium, tellurium, palladium, arsenic, rhenium, iron, lead, zinc, and sulfur.

To minimize transportation costs, mills are almost always located close to the mines. The value of the concentrates is high enough to allow some flexibility in smelter location. Still, most smelters are located near the mills which supply them or on tide water or rail head in order to receive concentrates from distant mills. Refineries can be located anywhere between smelters and fabricators, since the transportation costs for blister and refined copper are about the same.

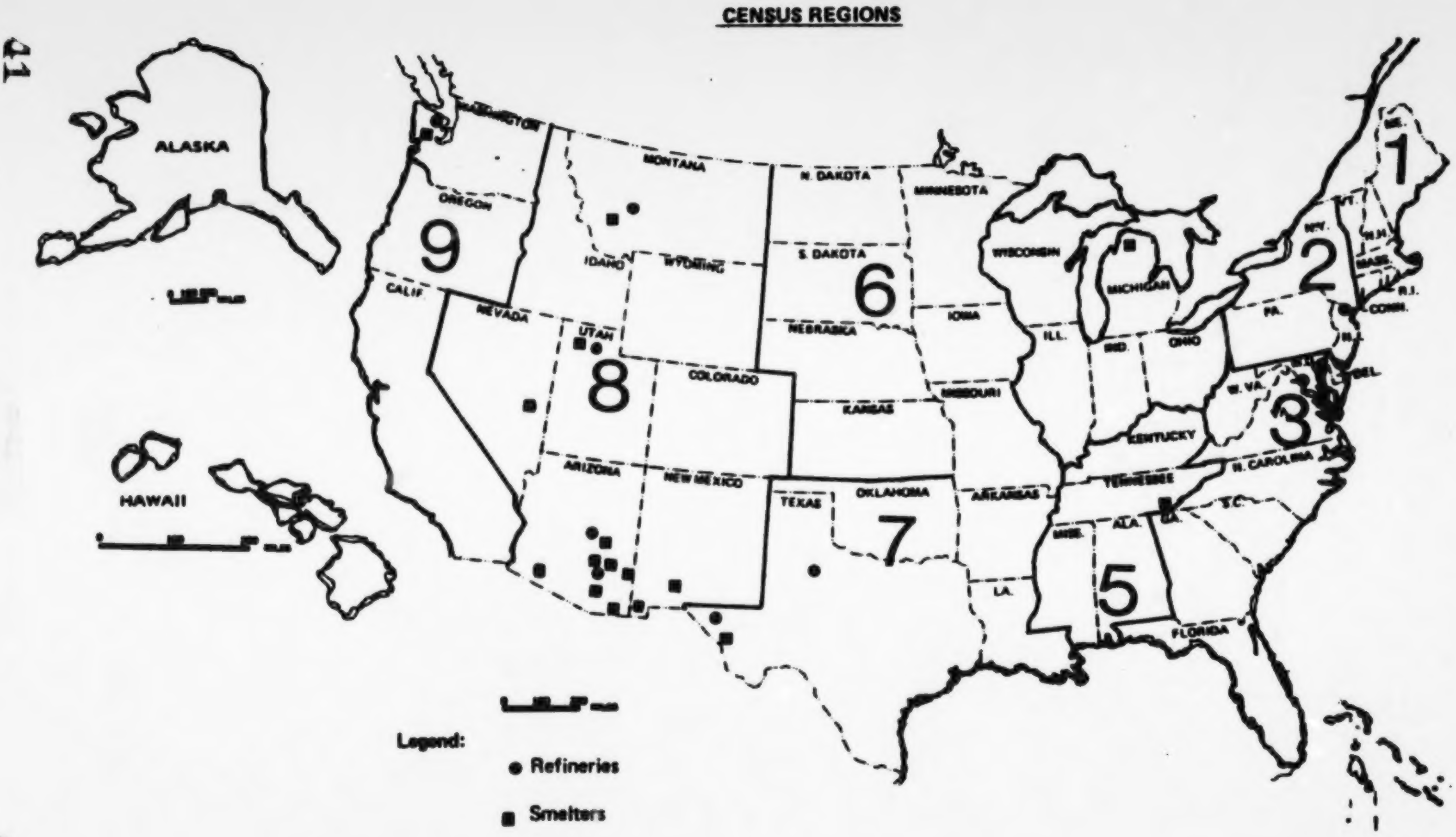
Most of the domestically mined copper is produced in five western states--Arizona, Utah, New Mexicc, Montana, and Nevada. Over 80 percent of total United States mine production is located in Arizona, Utah and New Mexico taken together. Arizona alone accounts for well over half the total United States mine production of recoverable copper (about 63 percent in 1976). As shown in Figure 3, the copper smelters and refineries are also concentrated in the western states.

COPPER PRODUCTION SYSTEM IN THE UNITED STATES, 1974
(Thousands of Short Tons of Copper Content)

FIGURE I-2


Net Ore Imports 36.7
Net Imports of Blister 205.1
Net Imports of Refined 177.2
Mine Production 1,597.0
Total Smelter Output 1,649.4
Total Refined Output 2,138.6
Total Refined Copper Supply 2,199.0
Crude Stocks & Other 63.8
Blister Stocks & Other 120.3
Refined Stocks & Other 116.8
Smelted From Scrap 79.5
Refined From Scrap 404.4
Total Copper Supply 3,167.0
Scrap Stocks & Other 3.0
Other Than Copper Base Scrap 21.1
Domestic Scrap 1,504.3
Copper Base Scrap 1,430.8
Scrap Recovered 1,451.9
Total Scrap Supply For Direct Consumption 968.0
Net Scrap Exports 70.5
Flows of ore, concentrate, and refined copper
Flows of scrap copper

Source: Compiled from Copper Development Association, Inc., *Copper Supply and Consumption, 1957–1975,* Tables 1 and 2.


CENSUS REGIONS
ALASKA
HAWAII
WASHINGTON
OREGON
CALIF.
NEVADA
IDAHO
MONTANA
WYOMING
UTAH
COLORADO
ARIZONA
NEW MEXICO
N. DAKOTA
S. DAKOTA
NEBRASKA
KANSAS
OKLAHOMA
TEXAS
MINNESOTA
IOWA
MISSOURI
ARKANSAS
LA.
WISCONSIN
MICHIGAN
ILL.
IND.
OHIO
KENTUCKY
TENNESSEE
MISS.
ALA.
GA.
FLORIDA
S.C.
N. CAROLINA
W. VA.
PA.
N.Y.
N.J.
DEL.
VT.
N.H.
ME.
MASS.
R.I.
CONN.
1
2
3
5
6
7
8
9
Legend:
● Refineries
■ Smelters

Source: Arthur D. Little, Inc., (1977)

FIGURE I-3: **LOCATION OF PRIMARY COPPER SMELTERS AND REFINERIES**

Different waste streams are generated during copper production. Large quantities of solid wastes (and in some cases, water effluents) are produced during mining and milling. However, in terms of complexity and cost, the air pollution problems of the smelters are currently the most important. In the United States, pollution control technology applied to standard reverberatory smelters can generally capture only about 50-70 percent of the sulfur in a smelter's feed materials through the manufacture of sulfuric acid. The use of new pyrometallurgical (state-of-the-art) technology would increase sulfur capture to over 90 percent. Even then, a typical smelter would generate 20 to 50 tons/day in the form of sulfur dioxide (SO_2) emissions. By contrast, EPA defines a major source as one that emits over 100 tons/year.

3. The Domestic Copper Industry in World Perspective

The United States, despite its declining share of total world consumption and production, still accounts for 24 percent of total world consumption and production, and over 18 percent of total world mine output (22 percent of world refined copper output).

In terms of its market structure, the domestic copper industry consists of the "primary" and the "outside" market sectors. The primary sector comprises firms which sell the bulk of their refined copper output (mostly from mined copper but also including some refined from scrap) on the basis of a commonly-followed domestic producers' price. The "outside" market, on the other hand, includes firms (e.g., merchants, scrap dealers and secondary refiners), which sell their copper output on the basis of one of several "outside" market prices.

The primary sector consists principally of the following firms: Kennecott, Phelps Dodge, Anaconda/ARCO, Magma/Newmont, Duval/Pennzoil, Cyprus, Asarco, Copper Range/Louisiana Land and Exploration, Inspiration, Cities Service, Ranchers Exploration, Hecla (in partnership with El Paso Natural Gas Company) and others. These firms are vertically integrated to different degrees from mining to refining and beyond into semifabrication. Several of the major copper producers are also major producers of other metals, such as lead and zinc, and others are aluminum producers. A number of producers participate jointly in foreign copper mining companies, notably in Canada, Africa, and South America.

The domestic copper industry has undergone important structural changes during the postwar period, with the entry of new firms at various stages of production, shifts in the degree of integration of firms, and important changes in ownership patterns (e.g., acquisision of copper companies by oil companies). As a result, the industry has become more diverse and somewhat less concentrated. In addition, the industry has become more complex or interdependent in terms of domestic or foreign joint-investments and buyer-seller relationships (e.g., custom/toll smelting and refining arrangements).

Internationally, copper output is highly concentrated in a relatively few countries. Along with the United States--still the largest single producer--five other countries (Canada, Chile, Zaire, Zambia, U.S.S.R.) together account for 71.2 percent of total world mine output in 1974.

There is considerable international trade in copper in all forms: ores, concentrates, blister, refined and fabricated products. The bulk of the world's copper exports is from the developing countries to Europe, Japan and the United States, with smaller amounts from Canada, South Africa and Australia. Japan and other industrial countries in Western Europe are heavily or even entirely dependent on external sources of primary copper.

During the postwar period, the copper industry has become not only more diversified geographically worldwide but also less concentrated as new firms have entered the industry. However, an opposite trend towards the nationalization of copper mining and processing operations in major copper exporting countries has brought about a significant shift in ownership patterns in the world copper industry in recent years. Chile, Zambia, Peru and Zaire formed in 1968 the Conseil Intergouvernemental des Pays Exportateurs de Cuivre (CIPEC), also known as the Intergovernmental Council of Copper Exporting Countries, which is patterned after OPEC, the oil cartel. These four original CIPEC countries together account for about 37 percent of Free World mine production in copper. With recent additions to its membership, CIPEC's share of internationally traded copper has increased to more than 70 percent.

4. Supply, Demand, Prices and Financial Performance

a. Supply

Copper reserves in the United States, mostly in the form of sulfide deposits, have been estimated at about 90 million short tons of copper (metal content), with an additional 320 million short tons in the form of "other" deposits, including undiscovered (hypothetical and speculative) deposits. The United States accounts for about 20 percent of known world copper reserves and other copper resources. Five states--Arizona, Utah, New Mexico, Montana, and Michigan--account for more than 90 percent of the total domestic reserves. The average ore grade of the domestic reserves held by such major producers as Kennecott, Phelps Dodge, Anaconda and Magma range in the neighborhood of 0.70-0.80 percent, the ore grade at some currently producing mines falls well below this range.

We expect sulfide reserves to continue to play a dominant role in meeting growing demand in the foreseeable future. In contrast with sulfide reserves, the oxide reserves are quite small and represent a far less important source of primary copper.

Although the bulk of domestic copper supply originates from primary or mined copper, secondary copper recovered from scrap also represents a significant source of copper supply, accounting for over 40 percent of domestic copper consumption. Copper obtained from scrap enters the supply stream in two forms: as refined copper, in which case it becomes indistinguishable from primary refined copper, and in the form of scrap, which is used directly. Although the supply of secondary copper is inelastic, it is not completely unresponsive to changes in price.

The supply of copper from the available reserves is characterized by long adjustment periods. Typically, investments are large, have long productive life-expectancy, and are perceived to be highly risky in view of cyclical fluctuations in copper prices. Because of the cyclicality of the copper industry, the threat of long-run substitution from other materials, competition from both the secondary and foreign producers plus other factors, investments are made with an expected long-run target rate of return. This defines the industry's "incentive price", that is, the price at which the firms would be willing to stay in business over the long-run, where revenues are sufficient to cover full costs, including a return on investment high enough to attract new capital. Hence, the long-run price of copper would tend to equal the long-run economic cost of copper (i.e., the price sufficient to induce continued investment at all stages of production).

The domestic copper industry is believed to have experienced sharp increases in production costs in recent years because of a combination of factors including declining ore grades, stagnant productivity, and steep rises in energy and other factor costs, and pollution control costs. Costs of mining and concentrating have traditionally formed, by far, the largest proportion of total production costs of refined copper. Smelting and refining costs have represented only a small proportion of the total cost, with smelters and refineries functioning mainly as "service" operations on fixed and relatively low profit margins.

During the postwar period, domestic smelter capacity growth has occurred mainly through incremental additions to existing smelter operations, rather than the construction of new "grassroots" (or greenfield) smelters. This growth in capacity was achieved by improved beneficiation techniques which increased the copper content of concentrates and also because of improvements in reverberatory smelting technology.

b. Demand

Demand for copper is a derived demand, since it is used as an intermediate input in the production of final goods which are ultimately demanded for consumption. In 1974, wire mills, which use only refined copper, accounted for 47 percent of total copper consumption. Brass mills, which consume refined copper and scrap in fairly equal proportions, accounted for about 39 percent of total consumption. Ingot makers, who use almost entirely scrap, were the third largest consumers at 7 percent. Foundries, consuming predominantly scrap, used about 4 percent, with powder plants, and "other industries" accounting for the remainder.

The major end-use industries consuming semifabricated goods are electrical and electronics products, building construction, consumer and general products, industrial machinery and equipment, transportation, and ordnance and accessories. Of these, the largest use of copper is in electrical equipment and supplies.

It is generally agreed that aluminum has been the most serious competitor to copper. The greatest replacement of copper has been in the power wire and cable sector, where some 40 percent of insulated power cable and over 90 percent of bare conductor applications are now provided by aluminum. Copper and aluminum are also mutually interchangeable in some heat exchanger applications.

Available econometric studies of demand for copper, including our own, generally indicate that in the short-run demand is quite inelastic with respect to both price and activity variables. The long-run elasticity estimates are all greater than the short-run estimates, indicating that the response of demand to relative prices and activity is more sensitive in the long-run. However, even the long-run estimates have been found in about half of the studies examined to fall in the inelastic range.

c. Prices

Historically, copper has been marketed at prices based on a number of different systems, some of them quite complex. Nevertheless, two basic pricing systems can be distinguished, the producer prices and prices related to quotations on metal/commodity exchanges.

Producer prices refer to prices established independently by the major primary producers. In the United States, the domestic producers' price is a set of nearly uniform price quotations used by the major domestic primary producers for a good part of the postwar period and by Noranda, one of the Canadian producers, for sales of primary refined copper in the United States. During the postwar period, about 75 percent of all refined copper production in the United States has been sold at the domestic producers' prices.

Copper is sold internationally (outside North America) by most producers most of the time, at prices related through various formulas to quotations on a metal/commodity exchange, principally the London Metal Exchange (LME). The LME and the New York Commodity Exchange (COMEX) are two organized metal exchanges (markets). Of the two, the LME is generally considered to be the more important in terms of turnover, physical deliveries, and its influence on the pricing of copper in general. Most of the "formulas" for pricing copper that are found on long-term contracts are related, in one way or another, to LME prices, since LME prices are generally considered to reflect, without delay, changes in the supply and demand situation worldwide. It is important to emphasize that the LME and COMEX are basically hedge and speculative markets, rather than physical markets.

In the United States the label "outside market" is used to denote all trade in copper, apart from sales made at the producer price by the primary producers. Thus, the "outside market" includes the secondary industry (including scrap dealers and secondary refiners), some of the smaller domestic producers of primary copper and transactions in physical copper on the LME and COMEX plus imports based on LME quotations.

Demand for copper is quite inelastic in the short-run, and the changes in copper supply are basically slow, characterized by long adjustment periods. Hence, wide swings in demand over the business cycle in industrial countries, combined with speculative activity in the very short-run on the two organized commodity exchanges,have contributed to the volatility of copper prices internationally.

Generally speaking, the domestic primary producers have tended to change their prices only slowly and not by the magnitude often experienced by the LME price. As a result, the producers' prices have generally remained well below LME prices during periods of strong-demand and above LME prices during periods of weak demand. In other words, there has existed a two-price system for refined copper in the postwar period which was characterized by periods of wide divergence between the outside market price for copper (i.e., the LME price) and the domestic producers' price A combination of factors appears to have had substantial restraining influence on the pricing decisions of the domestic primary producers which resulted in the two-price system. These factors include the actual (as well as the expected) threat of long-run substitution in favor of aluminum, some competition from secondary producers, the apprehension that domestic customers might shift to overseas suppliers if the domestic producers' price remained above the LME price over a prolonged period, the presence of United States government stockpiles, and the threat of governmental intervention (e.g., price controls).

d. Financial Performance

In the past decade, the United States copper industry has experienced modest growth in sales, low return on invested capital, eroding profit margins and higher debt, reflecting the combined pressure of inflation, higher cost of capital, increased capital requirements for environmental control and the worst recession during the postwar period.

Overall profitability for the copper producers, in terms of operating margin on sales, declined from about 23 percent in 1967 to 19 percent in 1974. Over the same period, profit margins for large industrial companies and manufacturers in general was rather stable. In terms of after-tax return on stockholders' equity, copper producers have shown a rate of return equal to the Federal Trade Commission (FTC) average for all manufacturing. However, the copper industry has been characterized by much greater volatility in its rate of return. This, in turn, stems from the cyclicality of the industry and fluctuations in copper prices.

Capital expenditures by most companies increased sharply in recent years. A significant portion (i.e., about 25 percent) of total industry capital expenditures over the period 1972-1975 has been for pollution abatement, mostly associated with SO_2 control at smelters. About 60 percent of the total represents investment in mining and milling capacity.

With capital expenditures increasing faster than internal cash generation (from earnings, depreciation, and deferred taxes), the cash-flow position of the companies has deteriorated. Consequently, there has occurred in recent years a sharp increase in external financing. Over the last five years, overall debt has approximately doubled, while equity has increased insignificantly. Indeed, some companies are believed to have temporarily reached prudent limits to debt in their capital structure and await higher earnings and stock prices to restore balance and financing flexibility.

F. LIMITS OF ANALYSIS

The objective of this study has been to assess the economic impact of the Clean Air Act Amendments of 1970 and 1977 and the Federal Water Pollution Control Act Amendments of 1972, as described above. Other environmental regulations, including those associated with occupational safety and health, have not been considered in this study.

The computerized econometric simulation modeling approach employed in this study focuses on the domestic copper industry and deals less comprehensively with developments in the rest-of-the-world. For the latter, the model relies on inputs (e.g., LME copper prices) based on analyses of economic growth in the other industrial countries, costs of production abroad, and mine capacity expansion in key copper exporting countries. A comprehensive worldwide modeling approach was contemplated but dropped, in view of resource constraints and competing priorities.

Over the next five-to-ten years, stagnant economic conditions or slow economic growth worldwide, and low LME copper prices, would represent a sharp and persistent reversal of the basic conditions that have prevailed during most of the postwar period. The econometrically estimated equations in the model reflect the prevalent postwar conditions. Hence, a sharp break with these postwar trends results in the model not yielding "strictly" convergent (i.e., mathematically perfectly consistent) solutions. That is, the model does not perform as well under such an unusual situation, which would represent a prolonged state of downturn for the domestic copper industry. From this we conclude that the domestic copper industry would be severely hurt under such pessimistic assumptions--a conclusion that would be intuitively apparent without the aid of a model.

This study has not examined the cost-effectiveness of the present set of environmental regulations. Such an investigation would identify the socially least-cost environmental control approaches, given the present regulations, assuming that national economic benefits emanating from such regulations are known or accepted at face value. Accordingly, little or no analysis of alternative approaches to pollution control has been performed in this study.

Further, no attempt has been made to quantify the incremental national economic benefits and costs associated with the present set of regulations or to quantify the benefit-cost gradients associated with alternative combinations of regulatory strategies. Such an investigation would have as its purpose the quantification of the national benefit-cost tradeoffs to choose socially optimal environmental control policies.

CHAPTER I

NOTES

1. Other studies in this series include petroleum refining, iron and steel, pulp and paper, capital markets, electric utilities, foundries, and others.

2. In most cases, local regulations and standards are such that Federal standards are controlling. An exception is the set of standards of the Puget Sound Air Pollution Control Agency which affects the Tacoma smelter.

3. Strong streams are defined as those containing over 4-5 percent SO_2.

II. PRODUCTION AND POLLUTION CONTROL TECHNOLOGY

A. INTRODUCTION

In this chapter, we discuss the conventional technology for producing copper and the pollution control technology which interfaces with that production technology to reduce emissions. A brief discussion of new technology is also included. The production of copper from primary (virgin) sources is based mainly on the exploitation of sulfide mineral deposits, and involves four stages of processing; mining, beneficiation or milling, smelting, and refining. Subsequently, the refined copper is melted and cast into various shapes for fabrication.

A small quantity of copper is produced from oxide ores by hydrometallurgical techniques. This involves the dissolution of copper in sulfuric acid solutions; concentration/purification, if necessary, by liquid ion exchange; and recovery of the copper by precipitation on scrap iron or via electrowinning. During mining and milling, large quantities of solid wastes (and in some cases, water effluents) are produced. However, in terms of complexity and cost, the air pollution problems of the smelters are currently the most important.

To minimize transportation cost, mills are almost always located close to the mines. The value of the concentrates is high enough to allow some flexibility in smelter location. Still, most smelters are located near the mills which supply them or on tide water or rail head in order to receive concentrates from distant mills. Refineries can be located anywhere between smelters and fabricators, since the transportation costs for "blister" copper from smelters and refined copper are about the same.

Considerable quantities of copper scrap are recycled by the primary producers, and by the producers of alloyed and unalloyed copper ingot. Such recycling involves melting for high-grade scrap but different types of refining for lower-grade scrap.

In the long-run, because the bulk of United States copper reserves is of the sulfide type, most of the copper would continue to be produced from sulfide concentrates. The use of new pyrometallurgical (non-reverb based) technology would increase sulfur capture to over 90 percent and decrease the energy consumed in smelting. Several hydrometallurgical processes have been developed for recovering copper from sulfide concentrates. While these processes are not energy-efficient, their attractiveness derives from the fact that such plants can be built on a much smaller scale than smelters and they convert sulfur in concentrates to forms other than sulfuric acid. Because oxide reserves are limited, the recovery of copper from copper oxide ores will not play a major role in total copper supply.

B. PRODUCTION TECHNOLOGY

Production of primary copper involves four basic activities: mining, milling, smelting and refining. Refined copper is then fabricated for various end-use markets. The four stages of primary production are:

- mining--where ore containing approximately 0.4 to 2 percent copper is mined;
- beneficiation--where the copper-containing minerals are separated from waste rock to produce a concentrate containing about 25 percent copper;
- smelting--where concentrates are melted and reacted to produce 98 percent pure "blister" copper; and
- refining--where blister copper is refined electrolytically to produce 99.9 percent pure cathode copper. Some of the new hydrometallurgical processes combine the functions performed by smelting and refining.

A generalized flowsheet of copper processing is shown in Figure II-1. Because previous reports and the published literature[1] contain detailed information on copper technology, only a brief summary is presented here.

1. Mining

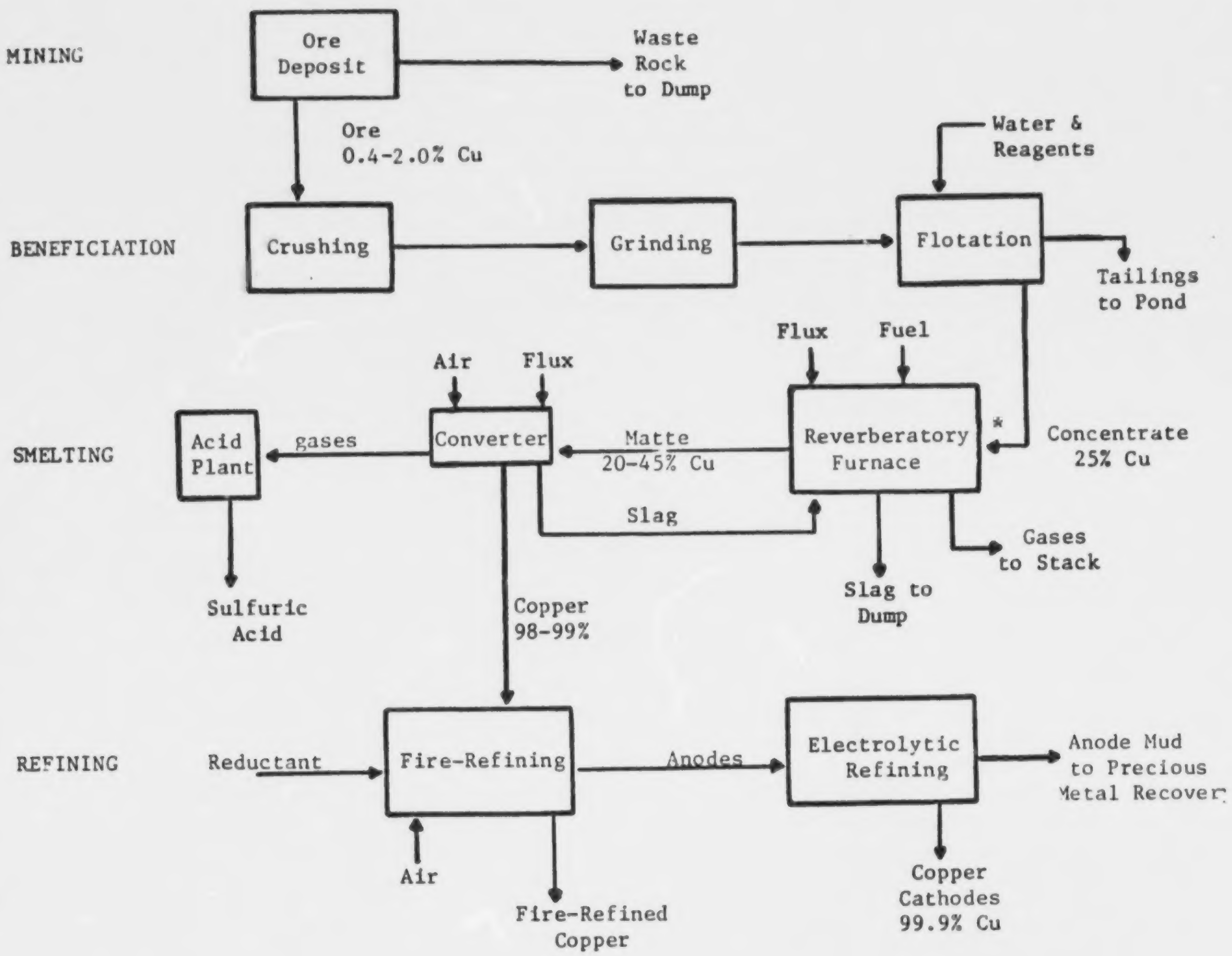
Copper-bearing materials are found near the surface or deep in the ground. Mining is the first step in their exploitation. About 85 percent of the total copper ore mined comes from open pits, where ore is removed from the surface rather than from underground workings; the rest comes from underground mines. Underground mining methods for copper ores involve caving and/or cut-and-fill mining.

2. Beneficiation/Concentration

From a processing viewpoint, copper ores can be classified in three categories--sulfide, native copper, and oxide. Each category requires different beneficiation processes. A sulfide ore is a natural mixture that contains copper-bearing sulfide minerals, associated metals, and gangue minerals (e.g., pyrites, silicates, aluminates)

FIGURE II-1

GENERALIZED FLOWSHEET FOR COPPER EXTRACTION FROM SULFIDE ORES


MINING
Ore Deposit
Waste Rock to Dump
Ore 0.4-2.0% Cu
Water & Reagents
BENEFICIATION
Crushing
Grinding
Flotation
Tailings to Pond
Flux
Fuel
Air
Flux
SMELTING
Acid Plant
gases
Converter
Matte 20-45% Cu
Reverberatory Furnace
*
Concentrate 25% Cu
Slag
Gases to Stack
Sulfuric Acid
Copper 98-99%
Slag to Dump
REFINING
Reductant
Fire-Refining
Anodes
Electrolytic Refining
Anode Mud to Precious Metal Recover
Air
Fire-Refined Copper
Copper Cathodes 99.9% Cu

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*Optional roasting step not shown.

that at times have considerable value (e.g., molybdenum, silver, gold, as well as other metals). The sulfide ores are treated primarily by crushing, grinding, and froth flotation to produce a concentrate (or several concentrates) of sulfide minerals; worthless gangue is rejected as tailings. Generally, only sulfide ores are amenable to concentration procedures. The output of this beneficiation process, concentrate, may contain 11-32 percent copper. Mine/mill output is typically defined in terms of recoverable copper content in concentrate form.

In native copper ores the copper occurs in metallic form. The Lake Superior district in Michigan is the only major source of ore in this type. Although the reserves of this ore are extensive, they contribute only a little of the total U.S. mine production of copper.

Finally, the non-sulfide, non-native ores of copper are termed "oxide" ores, the copper oxide content being measured by and synonymous with solubility in dilute sulfuric acid. An "oxide" copper ore can contain copper oxide, silicate or carbonate minerals and gangue. In the Southwestern United States, many deposits have a capping of oxide ore below which is a transition zone of various mixtures of oxide and sulfide copper minerals and then the primary sulfide deposit. The oxide ores have been treated metallurgically in a variety of ways, the character of the gangue minerals having a very important bearing on the type of metallurgical treatment used. In the United States, however, oxide ores are treated primarily by leaching with dilute sulfuric acid. Copper is recovered in metallic form from leach solution by precipitation on iron scrap (cementation) or by electrowinning from the solution as discussed in detail later in this chapter.

Commonly associated with copper are minor amounts of other metals whose presence can have a beneficial or a harmful effect on mine profitability. Molybdenum, lead and zinc are valuable only if recovered as separate sulfide concentrates by differential flotation. Minor amounts of selenium, tellurium, and precious metals stay with the copper during milling and smelting and are extracted during electrolytic refining. Of these, the precious metals can have a major beneficial effect if present. Arsenic, antimony and bismuth, as well as lead and zinc in the ores, cause problems in standard pyrometallurgical processing and electro-refining, and their presence above certain levels results in a cost penalty. Nickel and cobalt can interfere with electrolytic refining, but they do not occur in significant amounts in the United States copper deposits.

3. Smelting

Because most United States copper is extracted from low-grade sulfide ores that require concentration, current pyrometallurgical practice for recovery of copper is fairly uniform from smelter to smelter and is adapted to treating fine-grained sulfide concentrates that consist mainly of copper and iron sulfides and gangue. Copper's strong affinity for sulfur and its weak affinity for oxygen as compared with that of iron and other base metals in the ore are the basis for the three major steps in producing copper metal from sulfide concentrates: roasting, smelting and converting.

a. Feed Materials

Flotation concentrates containing from 15-30 percent copper constitute the bulk of the feed to the smelters. In addition, smelters will charge copper precipitates containing 70-85 percent copper, siliceous flux and limestone.

b. Drying

The flotation concentrates received by the smelter are a wet filter cake and can contain 10-15 percent moisture. Cement copper can contain as much as 30 percent moisture. The charge to a reverberatory furnace can be dried so that its overall moisture content is 4-8 percent without unduly increasing dusting problems in the reverb. The removal of moisture in drying reduces the fuel requirements in the reverb. Also the drier acts as a blender for homogenizing the charge. Rotary or multiple hearth driers are used for drying the feed materials.

c. Roasting

About half the copper smelters in the United States roast their charge prior to feeding in the reverberatory furnace. The older smelters use multiple hearth roasters for this purpose while the new smelters used fluidized bed roasters.

The object of roasting copper sulfide concentrates is to regulate the amount of sulfur in the materials and to remove certain volatile impurities such as antimony, arsenic, and bismuth. In modern practice, the grade of the concentrate is controlled sufficiently at the concentrator and roasting is not essential to control the sulfur content of the charge. However, in the case of custom or toll smelters, the composition of feed materials can vary widely and roasting is practiced to blend and control the sulfur content of the charge.

Elimination of some of the sulfur in roasting results in a higher grade matte in the reverberatory furnace and decreases the oxidizing load on the converters. Sulfide roasting can be autogeneous; additional fuel is not required. The charging of hot roasted calcines into the reverberatory furnace can decrease its fuel consumption per ton of charge by about 40 percent and, consequently, increase reverb capacity. In addition, roasting also reduces the emissions of sulfur dioxide from the reverb. The reason for this is as follows: The two major constituents of concentrates utilized by almost all the U.S. smelters are chalcopyrite, $CuFeS_2$, and pyrite, FeS_2. These minerals contain sulfur that is loosely held or "labile" which is given off by melting the minerals.

$$2CuFeS_2 = Cu_2S + FeS + S$$

$$FeS_2 = FeS + S$$

Cu_2S and FeS form matte, whereas the labile sulfur reacts with oxygen in the reverb gases to form SO_2. Removal of the labile sulfur during roasting can reduce emissions from the reverb. Also the lower fuel requirement per ton of charge when using calcine smelting reduces the volume of reverb off-gases.

Both types of roasters (multiple hearth and fluidized bed) usually operate around 1200°F. Sulfur dioxide concentration in the wet off-gas is usually 2-10 percent with multiple hearth roasters and varies because of dilution with air. With fluid bed roasters the wet off-gases can run 12-14 percent sulfur dioxide. Both types of roasters involve handling and collecting of large quantities of hot abrasive dust which can lead to high maintenance costs.

d. Reverberatory Furnace Smelting

Roasted and unroasted materials are melted after mixing with suitable fluxes in reverberatory furnaces. Liquid converter slag is also charged into the reverberatory furnace to recover its copper content. Heating of the charge is accomplished by burning fuel in the furnace cavity, the heat being transmitted to the charge primarily by radiation from the roof, walls and flame.

Most of the reverbs in the United States use natural gas/fuel oil as a fuel and only a few use powdered coal. The maximum smelting capacity of a reverb is limited by the amount of fuel that can be burned (a function of reverb shape and size) and the quantity of heat required by a unit weight of charge. Reverb throughput can be increased by drying the charge, preheating the charge by roasting and by preheating or enriching the combustion air.

In the reverberatory furnace, copper and sulfur form the stable copper sulfide, Cu_2S. Excess sulfur unites with iron to form a stable ferrous sulfide, FeS. The combination of the two sulfides, known as matte, collects in the lower area of the furnace and is removed. Such mattes may contain from 15-50 percent copper, with a 40-45 percent copper content being most common, and also contain impurities such as sulfur, antimony, arsenic, iron, and precious metals.

The remainder of the molten mass containing most of the other impurities and known as slag, being of lower specific gravity, floats on top of the matte and is drawn off and discarded. Slags in copper smelting are ideally represented by the composition $2FeO.SiO_2$, but contain alumina from the various charge materials and calcium oxide which is added for fluidity. Since reverb slags are discarded, the copper contained in the reverb slag is a major cause of copper loss in pyrometallurgical practice. The concentration of copper in the slag increases with increasing matte grade. This behavior limits the matte grades normally obtained in conventional reverberatory practice to below 50 percent Cu.

When using a reverb for green charge smelting, 20 percent to almost 45 percent of the sulfur in the feed is oxidized and removed from the furnace with the off-gases. The wet off-gases can contain 1.5-3 percent sulfur dioxide. When using calcine smelting, sulfur dioxide evolution is lower and about 10-15 percent of the sulfur in the unroasted feed material is contained in the reverb off-gases. SO_2 concentration in the wet off-gases in this case can vary between 0.5 to 1.5 percent.

The hot gases from the reverb are cooled in waste heat boilers which extract up to 50 percent of the sensible heat in the gases. A considerable amount of dust is removed in the waste heat boiler and the gases are further cleaned in electrostatic precipitators before venting to the atmosphere.

e. Converting

Matte produced in the reverberatory furnace is transferred in ladles to the converters using overhead cranes. The converters used in copper smelting are of the cylindrical Pierce-Smith type, the most common size being 13' x 30'. Air is blown from the side through a series of openings called tuyeres. During the initial blowing period (the slag blow) FeS in the matte is preferentially oxidized to FeO and Fe_3O_4 and sulfur is removed with the off-gases as SO_2. Flux is added to the converter to combine with iron oxide and form a fluid iron silicate slag. When all the iron is oxidized, the slag is skimmed from the furnace leaving behind "white metal" or molten Cu_2S. Fresh matte is charged into the converter at this stage and the slag blowing continued until a sufficient quantity of white metal has accumulated. When this happens, the white metal is oxidized with air to blister copper during the "copper blow." The blister copper is removed from the converter and cast or subjected to additional fire refining prior to casting. Converter blowing rates can vary between 12,000 to 30,000 scfm of air. Also, the SO_2 content of the off-gases is lower during "slag blow" than during "copper blow."

Cooling of the hot converter gases is necessary in order to prevent thermal damage to the dry gas cleaning equipment such as cyclones or electrostatic precipitators. Traditionally, this cooling was accomplished by adding dilution air that varied from 2-6 times the converter off-gas. With dilution air, SO_2 concentrations in the converter off-gases are from 1-7 percent. With close fitting hoods or with Hoboken converters, the off-gases can have 4-10 percent SO_2. However, when dilution air is not used, cooling devices such as waste heat boilers, air/gas heat exchangers or water sprays are necessary.

With proper hooding, the converter off-gas is sufficiently high in sulfur dioxide so as to be suitable for sulfuric acid manufacture, but converting by its very nature is a batch operation and the off-gas flow rates vary widely. In the smaller copper smelters which use two or three converters, the scheduling of converter blows in order to obtain relatively steady flows to the acid plant is a difficult problem.

4. Refining

The blister copper produced by smelting is too impure for most applications and requires refining before use. It may contain silver and gold, and other elements such as arsenic, antimony, bismuth, lead, selenium, tellurium, and iron. Two methods are used for refining copper--fire refining and electrolysis. Electrolytic copper is refined by electrolytic deposition, remelted, and cast in commercial shapes, while fire-refined copper is refined by using only a pyrometallurgical process.

The fire-refining process employs oxidation, fluxing and reduction. The molten metal is agitated with compressed air; sulfur dioxide is liberated, and some of the impurities form metallic oxides which combine with added silica to form a slag. Sulfur, zinc, tin, and iron are eliminated almost entirely, and many other impurities are partially eliminated by oxidation. Lead, arsenic, and antimony can be removed by fluxing and skimming as a dross. After the impurities have been skimmed off, copper oxide in the melt is reduced to metal by inserting green-wood poles below the bath surface (poling). Reducing gases formed by pyrolysis of the pole convert the copper oxide in the bath to copper. In recent years, reducing gases such as natural gas, reformed natural gas or ammonia have been used.

If the original material does not contain sufficient gold or silver to warrant its recovery, or if a special purpose silver-containing copper is desired, the fire-refined copper is cast directly into forms for industrial use. If it is of such a nature as to warrant the recovery of precious metals, fire refining is carried only to insure homogeneous anodes for subsequent electrolytic refining.

A major portion of United States blister output is electrolytically refined. In electrolytic refining, blister copper cast in anode shape and cathodes (thin copper sheets prepared separately) are hung alternately in plastic-lined or lead-lined concrete electrolytic cells that contain the electrolyte--essentially a solution of copper sulfate and sulfuric acid. When current is applied, copper is dissolved from the anode and an equivalent amount of copper plates out of solution on the cathode. Such impurities as gold, silver, platinum-group metals, and the selenides and tellurides fall to the bottom of the tank and form anode slime or mud. Arsenic, antimony, bismuth, and nickel enter the electrolyte. The electrolyte has to be treated to prevent the buildup of these impurities since they would have a deleterious effect on cathode purity. After the plating cycle is finished, the cathodes are removed from the tanks, melted, and cast into commercial refinery shapes. Anode scrap is remelted to form fresh anodes. The copper produced has a minimum purity of 99.9 percent.

5. Hydrometallurgy of Oxides

About 10-15 percent of the United States copper production comes from oxide sources. The hydrometallurgical treatment of such ores with dilute sulfuric acid to dissolve the contained copper is an old established technology. Since surplus sulfuric acid is available near the mines as a result of pollution control measures at smelters, acid leaching of mine waste dumps and mill tailings is widely practiced in addition to the leaching of oxide ores mined specifically for this purpose. Since many of these materials contain limestone, such a leaching process indirectly disposes the acid by neutralization.

Once in solution, copper is recovered either by precipitating on iron scrap or via LIX (liquid ion exchange)-electrowinning. In the first case, scrap iron is reacted with the pregnant leach solution in precipitation cones or in launders. Iron consumption in this reaction is several times the stoichiometric amount and is typically 2-3 lb iron/lb copper precipitated. Precipitated copper or cement copper is usually shipped to a smelter for processing.

In the LIX-electrowinning process, the pregnant solution is contacted with a liquid ion exchange (LIX) reagent. The LIX reagent is typically dissolved in an organic liquid such as kerosene, which is relatively insoluble in water. During contacting, copper in the pregnant leach solution preferentially transfers to the organic phase. The copper-depleted leach liquor is then recycled to the leaching system. The loaded organic liquid is next contacted with a strongly acidic aqueous solution (recirculating cell electrolyte) which strips copper from the organic phase. In this fashion, LIX takes copper from a dilute impure aqueous solution (leach liquor) and selectively transfers it to a relatively pure, concentrated solution suitable for electrowinning. The copper-containing solution is next electrolyzed in electrowinning cells, i.e., cells with insoluble anodes where copper is plated from the solution onto the cathodes. Cathodes from LIX-electrowinning approach the quality of electrorefined cathodes, but usually contain some impurities carried over from the "insoluble" anodes.

C. FORMS OF COPPER

Both electrolytic and fire-refined copper are sold in several classes of regular or standard refinery shapes (consisting mainly of horizontally cast wirebars, cathodes, ingots, and ingot bars, cakes, slabs and billets) and as copper powder. The shapes are largely determined by the requirements of the fabricators' equipment.

For analytical purposes, the 40 distinct types of refined copper classified and graded by the American Society for Testing Materials (ASTM) can be collapsed into "refined copper" as a generic category, for two reasons. First, many users can to some extent substitute the various types of copper. For example, brass mills and foundries are fairly flexible. Second, copper producers possess the flexibility to produce more of one form and less of another. In the short run, both producers and fabricators have much less flexibility. However, for periods greater than six months there appears little reason to distinguish among various types of refined copper in explaining the behavior of the market for refined copper. Further, market institutions indicate that it is reasonable to work in terms of refined copper, since a considerable degree of flexibility is allowed in substituting one type of copper for another and the producers' price for various types of copper shapes is generally stated in terms of a differential from the price of electrolytic copper wirebars.

D. THE SECONDARY INDUSTRY

The term "primary metal" refers to metal recovered from ores or virgin sources. The term "secondary metal" came into wide use before it had acquired a singular meaning and still carries misleading connotations. It is important to recognize that "secondary" pertains only to origin and not to quality. That is, secondary refined copper is physically equivalent to a corresponding grade of virgin refined copper. The term means only that the copper was recovered from scrap rather than from copper ore. Secondary copper loses its identity, except statistically, as soon as it is produced. It is not possible, for example, to determine whether a copper wirebar was derived from the scrap charged to a converter, or whether a brass ingot is made from remelted brass scrap or from primary alloys.

There are three major categories of scrap users: primary producers, producers of unalloyed copper and producers of alloyed copper including ingot producers, foundries, and brass and bronze mills. The primary industry will purchase scrap for process reasons (e.g., cooling of converters) and also to supplement the production from primary sources. The producers of unalloyed and alloyed copper are labelled the secondary copper industry.

The secondary copper industry utilizes a variety of processes to melt and refine copper scrap. Melting units include blast furnaces, reverberatory furnaces and electric furnaces. Refining is achieved via fire-refining or electrolytic refining. Often, product specifications are reached by diluting lower-grade secondary copper with purer grades in order to minimize the need for refining.

Copper scrap, as a generic term, refers to a variety of materials. There are five classifications of unalloyed copper scrap and more than 30 classifications of copper base or alloyed scrap. Some types of scrap are virtually pure copper, while others are alloys, or mixtures of alloy types that have copper contents ranging down to as little as 30 percent. Refinery slags, dross, skimmings and ash, which sometimes have even lower copper contents, are regarded as secondary material, since they are treated by the secondary copper industry, although technically they are not scrap copper. Small quantities of copper are also recovered from non-copper base scrap.

Finally, alloyed copper, which refers to alloys of copper and other metals, consists of "yellow brass" and other distinctive types of alloyed copper scrap used by fabricators (foundries and mills) as a convenient way of arriving at a fabricated product made of a particular alloy. Rather than purchasing pure constituent metals, making the alloy and then fabricating it, a fabricator may find it convenient to purchase one of the many types of copper alloys as scrap.

E. POLLUTION CONTROL TECHNOLOGY

1. Introduction

The major emissions at the mining and milling stage of production are solid wastes and water. Except for dust emissions, air pollution is not a problem. Of all the environmental regulations that impinge on the four segments of the domestic copper industry, the air pollution regulations that affect the smelters are currently the most important. The two pollutants of major concern at this time at the primary copper smelting stage of production are air-borne particulates and sulfur dioxide (SO_2). Described below is the process technology required for pollution control.

2. Pollution Control Technology for Conventional Smelting

At conventional copper smelters, both particulates and SO_2 are generated at several individual sources, with distinctive characteristics for the off-gas or emissions at each source. For each of these streams, many factors determine which of the air pollution control methods (or combinations) can best be used.

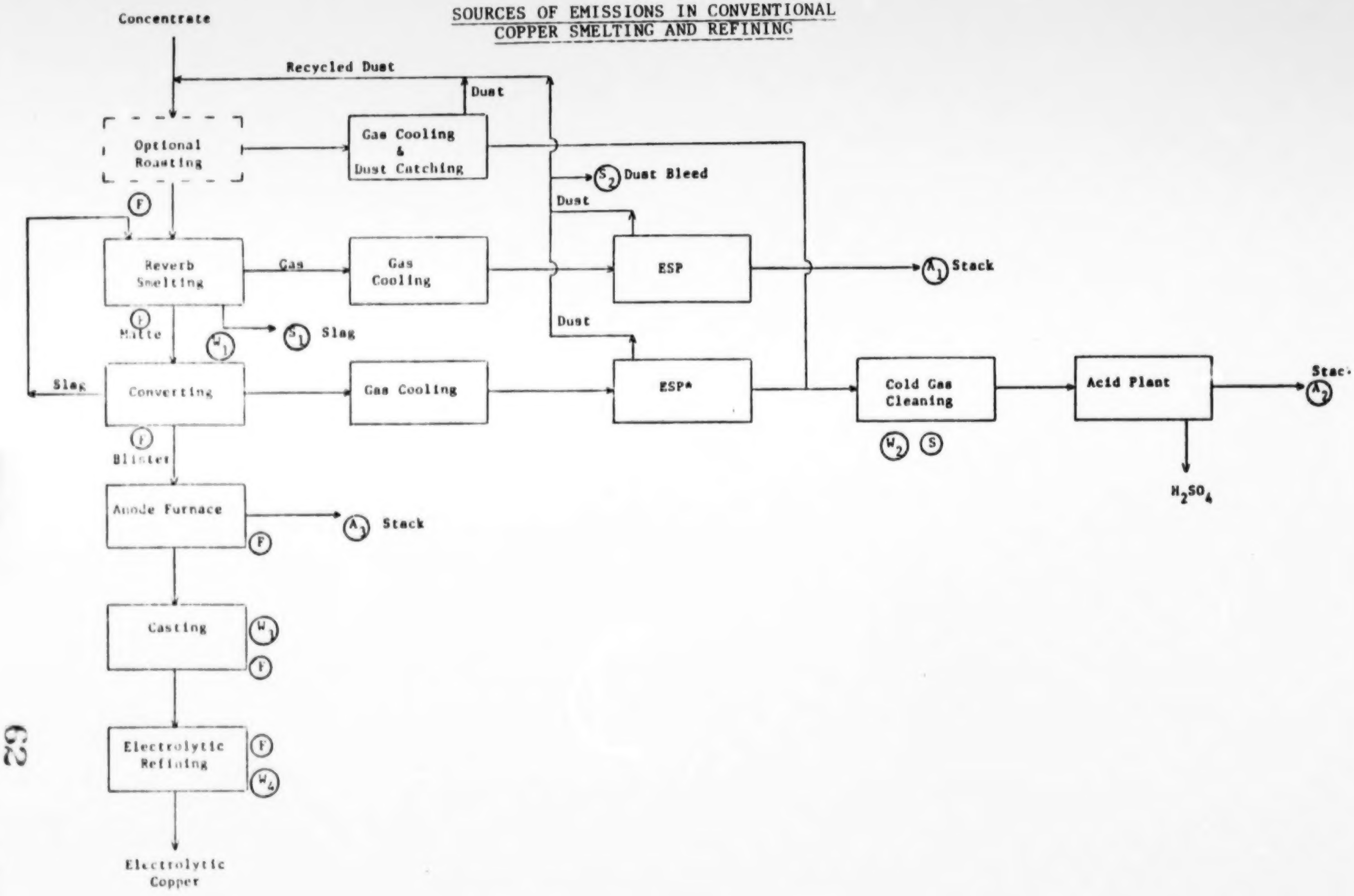
There are two principal methods of control: (1) physical removal of the potential pollutant from the carrying gas stream before discharge to the environment and subsequent disposal, or (2) actual reduction in the emissions generated by the process. If pollution is defined and measured in terms of concentration levels of a contaminant in the local ambient air, a third control method is the dispersion of the contaminant combined with changes in the operating rates. Figure II-2 is a schematic flow diagram of the conventional smelting and refining process. The sources of emissions are shown in four categories: air, solid, water and fugitive. The last category includes air emissions that come from diffuse sources. Table II-1 shows the magnitude of these streams and the major constituents.

3. Air Pollution

Existing copper smelters have to meet Federal Ambient Air Quality Standards for particulates ($75\ \mu g/m^3$) and sulfur oxides ($80\ \mu g/m^3$--primary; annual mean). New copper smelters have to meet New Source Performance Standards in addition. (See Chapter IX for a discussion of the many regulations on pollution control requirements). Existing copper smelters reduce the sulfur dioxide concentrations in their vicinity by: (1) capturing SO_2 in gas streams as sulfuric acid (by the contact process) or as liquid SO_2 (using DMA scrubbing); (2) using a tall stack to disperse dilute gas streams; and (3) curtailing production.

FIGURE II-2

SOURCES OF EMISSIONS IN CONVENTIONAL COPPER SMELTING AND REFINING


Concentrate
Recycled Dust
Dust
Optional Roasting
F
Gas Cooling & Dust Catching
S2 Dust Bleed
Dust
Reverb Smelting
Gas
Gas Cooling
ESP
A1 Stack
F
Matte
W1
S1 Slag
Dust
Slag
Converting
Gas Cooling
ESP*
Cold Gas Cleaning
Acid Plant
Stac.
A2
F
Blister
W2
S
H2SO4
Anode Furnace
A3 Stack
F
Casting
W1
F
Electrolytic Refining
F
W4
Electrolytic Copper

Effluent Types: Ⓐ - Air; Ⓦ - Water; Ⓢ - Solid Wastes; Ⓕ - Fugitive

*ESP = Electrostatic Precipitator

TABLE II-1

EMISSIONS FROM CONVENTIONAL SMELTING

Stream	Stream Size	Major Constituents
• Air Pollution		
A-1 - Reverb Gas	82,000 SCFM	SO_2: 1-2%; O_2: 5%; Particulates: 50 µg/NM^3
A-2 - Acid Plant Tail Gas	38,800 SCFM	SO_2: 0.2%
A-3 - Anode Furnace Gas	NA	Flue Gas, Some SO_2, Particulates
• Water Pollution		
W-1 - Slag Granulation	50,000 liters/kkg	TDS, SSS
W-2 - Acid Plant Blowdown	14,000 liters/kkg	TDS, TSS, Acidity
W-3 - Contact Cooling	7,800 liters/kkg	TDS, TSS (usually recycled)
W-4 - Black Acid Bleed	700 liters/kkg	Acidity, TDS, TSS
• Solid Wastes		
S-1 - Reverb Slag	3 tons/ton Cu	Iron Silicates
S-2 - Dust Bleed	0.3 tons/ton Cu	Copper Oxides, Minor Elements

The contact sulfuric acid process is well established for treating SO_2-containing off-gases from metallurgical plants. Modern contact acid plants require at least 4.5-5 percent sulfur dioxide in the feed gas in order to operate autogeneously, i.e., without external fuel. For lower concentrations of SO_2 an additional fuel input is required. The acid-plant size is primarily a function of the volume of gas handled. Hence, for a constant acid output, an acid plant operating on more dilute gases is much larger (and more expensive) than an acid plant operating on more concentrated gases. With the currently used vanadium pentoxide catalysts, the upper level of SO_2 concentration in the feed gas to an acid plant is between 7 and 9 percent. Gas streams more concentrated than this require dilution or specially designed plants.

Only one smelter practices DMA scrubbing of converter gases to produce liquid SO_2 for sale or for enrichment of feed gas to an acid plant.

The tall stack discharges sulfur dioxide at such heights that the gas is diluted when dispersed into the lower atmosphere. It is possible to heat the stack gases to increase plume height for additional dispersion and dilution. Because tall stacks can disperse and dilute when used in conjunction with other means of limiting emissions, no simple relationship is available to predict ambient concentrations as a function of percent sulfur recovery. Computer modeling has to be used for this purpose. The overall control strategy has to be well defined and local weather patterns have to be considered.

The third method for controlling sulfur dioxide concentrations at ground level is to curtail production when adverse weather conditions prevail. This method has been referred to as "closed loop control" or as a Supplementary Control System (SCS) when it is based on monitoring sulfur dioxide concentrations at ground level at various sites in the areas surrounding the smelter and using this information to control the smelter operating rate. When ground level concentrations increase as a result of adverse weather conditions, the smelter operation is curtailed to reduce the emission rate.

Most copper concentrates contain more sulfur than copper, e.g., 31 percent sulfur versus 25 percent copper. About 1 to 2 percent of the sulfur entering the smelter is lost in the slag and perhaps 3 to 5 percent evolves as fugitive emissions. The remaining sulfur is in gaseous effluents from the roaster, reverb and converters. Typical percentage sulfur distributions in conventional smelting are:

	Calcine Smelting	Green Charge Smelting
Roaster	20	-
Reverb	25	40
Converter	50	55
Slag and Fugitives	5	5
Total	100	100

The conventional smelting process evolved in geographical areas where acid markets were unavailable and all SO_2-containing gas streams were vented to the atmosphere (after particulate control, if necessary). Thus, conventional technology used gas-handling techniques (for example, dilution air for cooling of converter gas) which would not be used if the stream were to be treated for SO_2 recovery. However, streams from the roaster (in some cases) and converter can be handled to minimize air leakage. This results in SO_2 concentration greater than 4 to 5 percent which is adequate for autogenous sulfuric acid manufacture--the least costly control technology for removing SO_2 from such streams. The reverb gases are a high-volume (up to 100,000 SCFM) and low-concentration (0.5 to 2 percent SO_2) stream that is not amenable to autogenous sulfuric acid manufacture.

With conventional smelting, as well as with the new smelting processes (discussed in the next section), SO_2 control is achieved via an "end-of-pipe" treatment facility, usually a sulfuric acid plant. However, changes in processing and in gas handling and gas cooling are necessary for proper interfacing between process units and pollution control units.

In addition to SO_2, the reverb gas contains particulates. The use of electrostatic precipitators permits the particulate emission levels established for copper smelters to be met.

4. Solid Wastes

In a copper smelter, slightly more than three pounds of solid waste are generated per pound of copper. The major waste stream is in the form of slag. Occasionally, this solid waste stream also includes stockpiled flue dust.

a. Slag

The converter slag is recycled to the reverb in order to recover its copper content. The slag tapped from the reverbatory furnace (and granulated in some cases) is disposed as an inert rock. Reverb slag is mainly an iron silicate, containing about 0.5 to 0.9 percent copper and minor elements in dilute form.

b. Flue Dust

The flue dust results from entrained particles and condensed effluents in the gas stream. Typically 3 to 6 percent of the total weight of solids entering the smelter is evolved as dust. Coarse particles are caught in the cooling chambers, while fine particulates are removed by electrostatic precipitators operating slightly above the dew point of the gas stream.

All flue dusts contain entrained copper and they are mostly recycled to the reverberatory furnace. They may also contain volatile impurities in a concentrated form. Excessive impurity build-up by dust recirculation would impair the quality of the blister copper. At times it is economical to process these dusts further in order to recover such metals as zinc, lead, arsenic, etc. Depending on the composition of the feed, a fraction of the dust generated may be diverted and either stored or sold to other specialized smelters which recover the contained metals.

5. Water Pollution

In a copper smelter and refinery the sources of wastewater are:

- slag granulation (if this is practiced);
- acid plant blowdown (i.e., blowdown from wet scrubbers ahead of the acid plant);
- metal cooling;
- spent electrolyte and washings; and
- storm water commingling with process wastewater.

The primary copper industry has to meet three specific effluent limitation guidelines. These are:

- Best Practical Control Technology Currently Available (usually referred to as BPT)--to be met by industrial discharges by 1977.
- Best Available Technology Economically Available (usually referred to as BAT)--to be met by 1983.

- New Source Performance Standards (NSPS)--to be applied to all new facilities constructed after the promulgation of the guidelines.

In order to meet the effluent limitations, the recommended treatment technology must remove suspended solids, adjust pH, and remove the specific heavy metals. The recommended technology (for both BPT and BAT) is lime treatment, settling, and any necessary pH adjustments and filtering. This technology is recommended because all of the heavy metals included in the proposed effluent limitations have a very low solubility in the alkaline pH range, and the addition of lime causes them to precipitate out of solution as hydroxides and carbonates. The metal precipitates, along with other suspended solids present in the wastewater, are separated from the wastewater stream by means of settling, and are withdrawn as a sludge. Since the wastewater is still at a high pH after this step, it is necessary to lower the pH. This step is usually performed in a separate basin.

Other recommended techniques for improving the effectiveness of the previously mentioned end-of-pipe treatment are: reuse of water in other operations; control of mine water drainage by modificaton of mining techniques, construction of diversion structures, or ditching; and use of solar evaporation to eliminate the discharge of excess water.

F. NEW PROCESS TECHNOLOGY

United States smelting technology evolved in a framework of low energy costs and in locations distant from sulfuric acid markets and urban population centers. Because of the relatively high cost of transporting sulfuric acid, its recovery was usually not economic. Also, SO_2 containing gases could be discharged to the atmosphere in remote locations. Thus the technology was not aimed at recovering sulfur values as sulfuric acid (as is the case in some other industrialized countries) and was not particularly efficient in its use of energy. Several changes have occurred in the past five years on the economic and regulatory scene which indicate that the currently used technology is not longer applicable for the construction of new smelters:

- Energy costs for smelting have increased rapidly. Cheap natural gas, the fuel used by most smelters is not now available to the smelters, particularly in peak demand months (winter), and might not be available at all in the future.

- Emissions of SO_2 to the atmosphere have to be controlled.

- The sulfuric acid produced by smelters cannot always be economically transported to traditional acid markets. It often has to be disposed of in the general vicinity of the smelter. The resulting availability of low-priced acid in the West has made it possible to use it in the manufacture of wet process phosphoric acid from low-grade western phosphate rock or to use it to leach mine dumps and low-grade deposits which could not otherwise be leached economically. An alternative is to neutralize the acid with limestone, as is being done indirectly by leaching copper ores high in limestone.

New process technology has evolved in response to various shortcomings of conventional technology and as a result of external constraints. This new technology falls into three major categories:

- New smelting processes (Outokumpu, Mitsubishi, Noranda, electric, top blown rotary converter--TBRC, etc.),
- Hydrometallurgical processing of sulfide concentrates (Arbiter, Clear, Cymet, etc.), and
- Hydrometallurgical processing of oxide/sulfide ores, mine dumps, etc.

The new smelting processes are more energy efficient and can reduce total energy required in smelting. They produce a concentrated stream of sulfur dioxide from the smelting unit which can be economically converted to sulfuric acid. The adoption of this technology would avoid the use of reverbs which produce dilute SO_2-containing streams. Sulfur capture would increase from about 50 to 70 percent for current technology to over 90 percent. The major shortcoming of the new processes other than electric smelting is their unproven applicability to impure smelter charge (charge high in As, Sb, Bi, Pb, Zn, Se, Te, etc.). Until this issue is resolved, the new processes would have to be utilized in smelters that smelt clean concentrates in regions where acid markets are available. All pyrometallurgical processes, conventional as well as new, offer significant economies of scale, the smallest economic size being approximately 100,000 tons/year of copper.

The hydrometallurgical processes for sulfide concentrates produce cathode copper directly, and release sulfur in the concentrates in forms other than SO_2. It may be feasible to build hydrometallurgical plants sized around 40,000 tons of copper per year at unit capital requirement which is about the same as that of a large (over 100,000 tons/year) copper smelter and refinery. The hydrometallurgical processes, in general, are not energy efficient and utilize more energy than pyrometallurgical processes and refining. Furthermore, the leached solid wastes will require land disposal into areas prepared to prevent groundwater leaching of soluble substances and to prevent airborne particulates.

Because such plants will probably be located generally in the semi-arid western United States, such a disposal area can be established with some degree of confidence. Overall, these processes are likely to be utilized in locations remote from sulfuric acid markets where a large smelter is not justified.

Sulfuric acid leaching of oxides is not a primary copper recovery process but can be considered as an acid neutralization/disposal technique that also recovers copper from resources previously considered sub-marginal. Since the typical western United States smelter locations are distant from major sulfuric acid markets, the sulfuric acid produced to minimize air pollution has to be utilized for leaching of marginal resources (mine dumps, tailings, oxide ores, etc.) or for making wet process phosphoric acid. The leaching of dumps and surface deposits without contamination of groundwater is possible in the arid West but might not be possible in other parts of the United States.

In the copper electrorefining area, there are several new developments which will allow the existing plants to significantly increase their productive capacity in the short-term at low cost and without affecting copper cathode quality. These techniques are based on improving electrolyte flow patterns, periodic reversal of current, automatic scanning of operations for process control, etc. Of these, periodic reversal of current (PRC) is the most promising and is already being adopted in many parts of the world.

About 40 years ago, the recovery of copper shifted from the treatment of small, high-grade deposits to the treatment of large, low-grade deposits. The technology of exploiting these low-grade deposits was based on large-scale mining, milling and concentration of sulfide ores. Since it appears that the bulk of the world's copper reserves are in the form of sulfides, this trend will continue with oxide ores being mined on an opportunistic basis but usually as an adjunct to the exploitation of sulfides.

There appear, on the technological horizon, two techniques which could alter the resource base or the costs of production. The large-scale mining of ocean nodules is expected to provide manganese, copper, nickel and cobalt. While the utilization/marketing of the manganese is potentially a problem, the costs of production of the other three metals would be "competitive" at current prices. The other technique is "solution mining" of low-grade deposits (sulfide and oxide) which, if technologically proven, could provide a fundamentally new way of exploiting low-grade deposits.

CHAPTER II

NOTES

1. See, for example, two previous reports prepared by Arthur D. Little, Inc. (ADL) for U.S. Environmental Protection Agency (EPA): Economic Impact of Anticipated Pollution Abatement Costs--Primary Copper Industry (1972) and Economic Impact of New Source Performance Standards on the Primary Copper Industry: An Assessment (October, 1974). Also, Extractive Metallurgy of Copper, Biswas and Davenport (Pergamon Press, 1976).

III. THE STRUCTURE OF THE UNITED STATES COPPER INDUSTRY

A. INTRODUCTION

Chapter II presented a discussion of the various stages of copper production from primary sulfide mineral deposits and gave a description of the conventional technology for producing copper and the pollution control technology which interfaces with that production technology to reduce emissions. This chapter describes the organization and key aspects of the structure of the United States copper industry.

Analysis of the competitive structure of an industry/market requires the examination of three interrelated areas: (a) structure, (b) conduct (behavior) and (c) performance. The three areas or concepts are interrelated in that the structure of a market is generally understood to determine the conduct (i.e., pricing behavior) of the participants in the market, and the conduct, in turn, is believed to determine the performance (e.g., financial) of the participating firms. The causal directions, however, are not always clear. This chapter is concerned mostly with the first of these three interrelated areas (i.e., structure) and only by implication with the second area. (Pricing is covered in Chapter VIII). The financial performance of the participating firms is discussed in the next chapter.

This chapter focuses on domestic copper supply, definition of domestic copper industry segments or markets on the basis of the pricing behavior of the participating firms, the geographical distribution of the industry, and the degree of concentration as well as vertical integration.

Most of the discussion will be concerned with the primary producer segment of the domestic copper industry (i.e., that portion of the industry concerned predominantly with supplying refined copper produced from virgin ore and blister rather than from scrap). We will, however, discuss relevant aspects of the secondary copper industry, as well.

The United States is the leading producer and consumer of copper in the world, accounting roughly for one-fifth of total world refined copper production, consumption and reserves. Except for certain periods in the past coinciding with military developments or unusual "demand crunch" periods, the United States has been nearly self-sufficient in copper.

About 98 percent of the domestic mine production of copper comes from ores mined primarily for their copper content, the remainder is recovered from complex or mixed base metal ores. The copper ores also are the source of significant quantities of byproducts and co-products such as gold, silver, molybdenum, nickel, platinum, selenium, tellurium, palladium, arsenic, rhenium, iron, lead, zinc, and sulfur.

Most of the domestically mined copper is produced in five western states--Arizona, Utah, New Mexico, Montana and Nevada. Over 80 percent of total United States mine production is located in Arizona, Utah and New Mexico taken together. Arizona alone accounts for well over half of total United States mine production of recoverable copper (about 63 percent in 1976).

Production of domestically mined copper accounts for a major share of the total United States refined copper supply stream. It should also be noted that refined copper from scrap, produced both by refineries and by "secondary plants" (i.e., numerous small smelters of scrap copper), makes an important contribution to total United States refined copper supply. Unrefined copper from new and old scrap, used directly, also represents, on its own right, a significant source of copper supply.

The domestic copper industry can be segmented into "primary" and "outside" market sectors, for analytical purposes, on the basis of the pricing behavior of the firms on the sellers' side. By this criterion, the primary sector consists of firms which sell the bulk of their refined copper output (mostly from mined copper but also including some refined from scrap) on the basis of a commonly-followed domestic producers' price. Firms participating on the "outside" market, on the other hand, are those which sell their copper output, regardless of its form (i.e., whether refined or scrap) and regardless of its origin (i.e., whether processed from mined copper--from domestic or foreign source--or refined from scrap) on the basis of one of several "outside" market prices explained in detail in Chapter VIII.

It should be noted, in this connection, that defining the structure of the domestic copper industry segments/markets on the basis of the pricing behavior of the participating firms presents considerable difficulties. For this reason, the "primary" and "outside" market designations used here should be taken as largely suggestive and not as definitive.

The primary sector consists principally of the following firms: Kennecott, Phelps Dodge, Anaconda/ARCO, Newmont, Duval/Pennzoil, Cyprus, Asarco, Copper Range, Inspiration, Cities Service, Ranchers Exploration, Hecla (in partnership with El Paso Natural Gas Company) and others. These firms are vertically integrated to different degrees from mining to refining and beyond into semifabrication. Further, in cases where a few of these firms are integrated forward into semifabrication, not all of the input requirements of these semifabricating subsidiaries are supplied by the parent-company's refined output. Several of the major copper producers are also major producers of other metals, such as lead and zinc, and others are aluminum fabricators. A number of producers participate jointly in foreign copper mining companies, notably in Canada, Africa and South America.

The United States copper industry, consisting predominantly of the "primary" sector, is highly concentrated. In 1974, four firms--Kennecott, Phelps Dodge, Anaconda, and Newmont--accounted for 64 percent of total United States mine production. Eight firms, including these four plus Duval, Cyprus, Asarco and Copper Range, accounted for 88 percent of the total. Seven firms--Asarco, Kennecott, Phelps Dodge, Newmont, Anaconda, Inspiration, and Copper Range--together represent virtually all of the United States smelter and primary refinery capacity.

Although highly concentrated, the domestic copper industry has undergone important structural changes during the postwar period, with the entry of new firms at various stages of production, shifts in the degree of backward or forward integration of new or old firms, and important changes in ownership patterns (e.g., acquisition of copper companies by oil companies). As a result, the industry has become more diverse and somewhat less concentrated. In addition, the industry has become more complex or interdependent in terms of domestic or foreign joint-investments and buyer-seller relationships (e.g., custom/toll smelting and refining arrangements).

B. INDUSTRY DEFINITION

For the purposes of this study, copper producers, or more generally, the copper industry, is defined in terms of the mining, milling, smelting and refining stages of production. Downstream fabricating and semifabricating operations, encompassing brass mills, wire mills, foundries, powder plants, etc., are not covered in this study, largely because most, if not nearly all, of the pollution abatement impact problem is concentrated at the mining through refining stages of production and particularly on the smelting stage where sulfur oxide emissions occur. These four stages of production are defined by the United States Bureau of the Census as follows:

1. SIC 1021--Copper Ores (Mining and Milling)

The copper ores industry includes establishments primarily engaged in mining, milling, or otherwise preparing copper ores. This industry also includes establishments primarily engaged in the recovery of copper concentrates by precipitation and leaching of copper ores. Establishments primarily engaged in the recovery of refined copper by leaching copper concentrates are classified in SIC 3331.

2. SIC 3331--Primary Copper (Smelting and Refining)

This industry comprises establishments primarily engaged in smelting copper from the ore and in refining copper by electrolytic or other processes. Establishments primarily engaged in rolling, drawing, or extruding copper are classified in industry 3351 (Copper Rolling and Drawing).

3. SIC 33412--Secondary Copper (Part of SIC 3341)

This industry (SIC 33412) comprises establishments primarily engaged in recovering copper from copper and copper-base alloy scrap by utilizing a variety of melting and refining methods (described in Chapter II). Establishments primarily engaged in assembling, sorting, and breaking up scrap metal, without smelting and refining, are classified in trade industries.

4. Part of SIC 5093--Scrap and Waste Materials

To complete the definition of the copper industry, in terms of producers/stages of production, we need to add establishments primarily engaged in assembling, breaking up, sorting and wholesale distribution of copper scrap (classified as part of SIC 5093--Scrap and Waste Materials).

It should be noted, in this connection, that scrap copper, which as a generic term refers to a variety of distinct materials, can be divided into two general categories--old scrap and new scrap. This distinction is important, although old scrap and new scrap are physically much the same. The quantity of new scrap generated each year is considerably larger than the quantity of old scrap which reaches the markets. Old scrap is composed of obsolete, worn out, or damaged copper products which have been discarded, such as old car radiators, discarded power lines, pipe and ship propellers. New scrap is composed of clippings, punchings, turnings, defective or surplus goods and drosses which are generated by the manufacturing process and fabricators. New scrap does not include "home scrap" or "turnaround", which are terms applied to materials recycled by fabricators without an intervening sale or transport over a considerable distance. Some types of scrap are specifically old scrap or new scrap, but usually a given type may be either.

Old scrap can be broadly classified into "low grade", "intermediate grade", and "high grade" material. Low grade material is recovered as refined copper by primary and secondary producers. Intermediate grade material is composed of alloy copper products. If the material is well sorted and the composition is known, it may be used directly by fabricators, especially by foundries. Otherwise it will usually be made into copper alloy ingot. High grade scrap, which is very nearly pure copper, may either be refined or used by fabricators as a substitute for refined copper.

Table III-1 gives a general statistical overview of the primary copper industry as defined above (i.e., SIC 1021 and SIC 3331, covering primary copper mining, milling, smelting and refining), with reference to three benchmark census years 1954, 1963 and 1972. It can be seen that while the number of establishments have remained fairly stable over the 1954-1972 period, total employment has shown some growth (approximately 1.3 percent per year). Value added, the industry's contribution to Gross National Product (GNP) has grown three-fold during this period in nominal terms or nearly doubled, in real or constant dollars terms.

C. AN OVERVIEW OF COPPER SUPPLY CHANNELS AND CONSUMPTION IN THE UNITED STATES

Figure III-1 is a simplified diagram showing the flow of copper supply in the United States in 1974 from principal sources, through the various stages of production. Two principal sources of copper can be immediately discerned: primary copper, produced from domestic and foreign ores, and secondary copper, obtained from scrap. Mined copper represents, of course, the major source of the nation's copper supply. Nonetheless, the contribution of scrap (copper-based and other than copper-based) to the total copper supply stream is not, by any means, negligible. It can further be observed that copper obtained from scrap enters the supply stream in two forms: as refined copper, in which case it becomes indistinguishable from primary or mined refined copper, and in the form of scrap, which is used directly.

These observations can be given numerical dimension by noting the following, with reference to 1974:

- 69.4 percent of the total copper supply of the United States (i.e., production adjusted for inventory changes, imports and exports) was in the form of refined copper produced from domestic and foreign ores and in part from scrap; the rest (i.e., 30.6 percent) was in the form of scrap copper used directly.
- Domestic mine production accounted for 74.7 percent of the nation's total refined copper output, 72.6 percent of total refined copper supply, and 50.4 percent of total copper supply from both primary and secondary sources.
- Most of the scrap recovered in the United States is used directly (i.e., 66.7 percent), without further refining, by semifabricators and end-users; the remainder is smelted and refined. Refined copper from scrap accounts for 22.6 percent of total refined output.

TABLE III-1

UNITED STATES COPPER INDUSTRY: GENERAL STATISTICS, 1954, 1963 AND 1972

Year and Industry Segment (SIC[a])	Establishments		All Employees		Production, Development, and Exploration Workers			Value added in Mining	Cost of Supplies, etc. and Purchased Machinery Installed	Value of Shipments and Receipts	Capital Expenditures
	Total (number)	With 20 Employees or More (number)	Number (1,000)	Payroll (million dollars)	Number (1,000)	Man-Hours (millions)	Wages (million dollars)	(million dollars)	(million dollars)	(million dollars)	(million dollars)
1954											
SIC 1021--Copper Ores (Mining and Milling)[b]	210	41	27.8	136.1	21.5	46.7	98.5	334.9	256.1	508.7	82.2
SIC 3331--Primary Copper (Smelting and Refining)	28	28	14.7	63.3	12.4	25.0	51.2	159.2	c	c	4.3
TOTAL	238	69	42.5	199.4	33.9	71.7	149.7	494.1	-	-	86.5
1963											
SIC 1021--Copper Ores (Mining and Milling)	160	41	26.5	187.3	21.4	45.3	142.4	417.1	340.2	670.2	87.1
SIC 3331--Primary Copper (Smelting and Refining)	33	33	14.9	96.1	12.7	25.8	77.9	285.5	970.0	1,245.5	13.1
TOTAL	193	44	41.4	283.4	34.1	71.1	220.3	702.6	1,310.2	1,915.7	100.2
1972											
SIC 1021--Copper Ores (Mining and Milling)	187	70	36.4	388.2	27.8	56.3	279.0	1,014.4	767.4	1,572.6	209.2
SIC 3331--Primary Copper (Smelting and Refining)	31	31	17.2	173.2	14.4	28.7	138.2	487.8	2,298.5	2,771.1	119.7
TOTAL	218	101	53.6	561.4	42.2	85.0	417.2	1,502.2	3,065.9	4,343.7	328.9

NOTES:

[a] Standard Industrial Classification.

[b] Excludes data for two copper ore establishments in Alaska with less than fifteen employees.

[c] Cost of materials and value of shipments are not shown since these figures contain extensive duplication.

SOURCES:

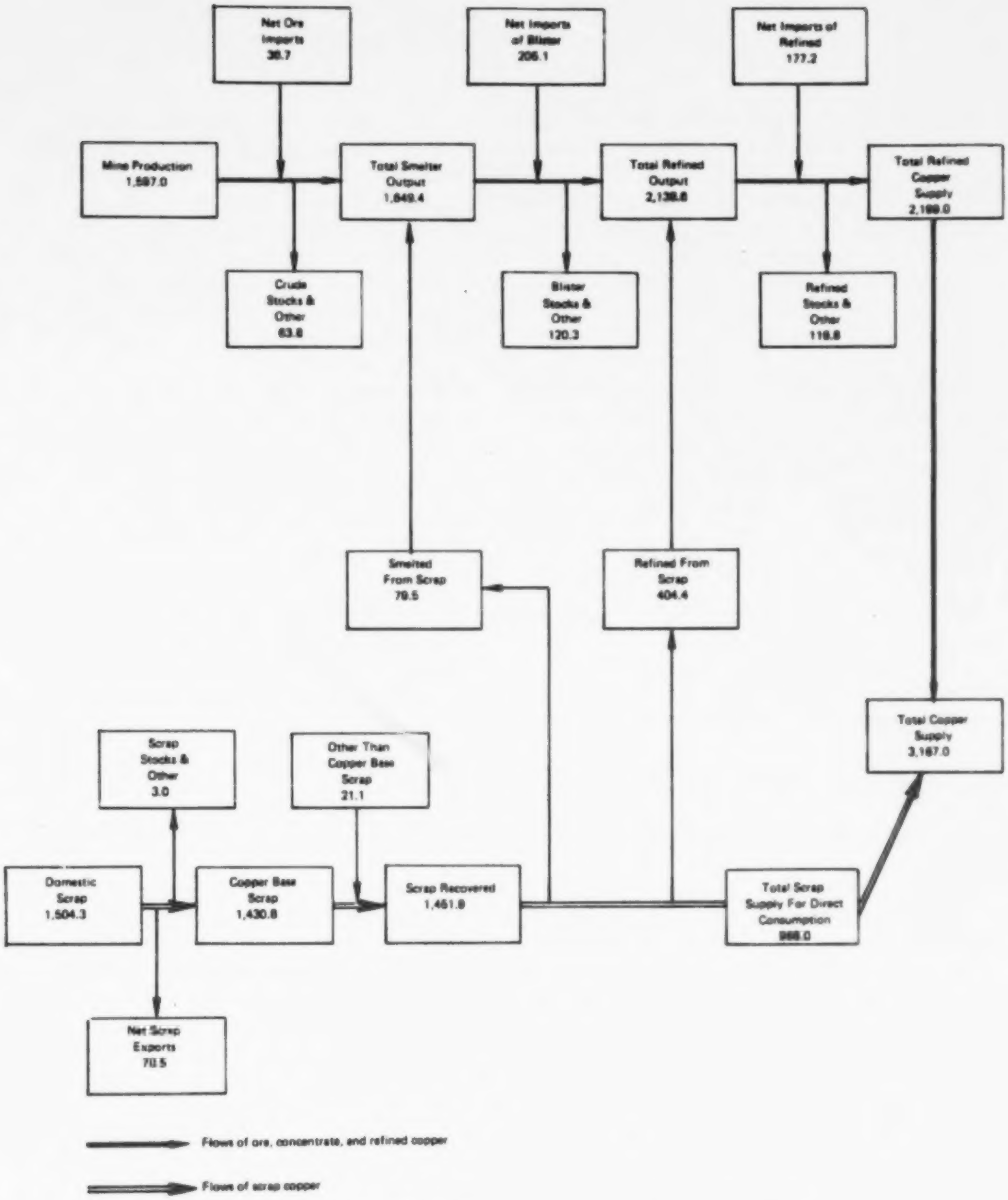
United States Bureau of the Census, U. S. Census of Manufactures: 1958, Vol. II, Industry Statistics, Part 2, Major Groups 29 to 39 (Washington, D.C.: U. S. Government Printing Office, 1961), p. 33C-7;

United States Bureau of the Census, Census of Mineral Industries, 1972, Subject, Industry; and Area Statistics (Washington, D. C.: U. S. Government Printing Office, 1976), p. 103-5.

United States Bureau of the Census, Census of Manufactures, 1972, Industry Series, Smelting and Refining of Nonferrous Metals and Alloys, SIC Industry Groups 333 and 334, MC72(2)-33C (Washington, D. C.: U. S. Government Printing Office, April 1975), p. 33C-7.

FIGURE III-1

COPPER PRODUCTION SYSTEM IN THE UNITED STATES, 1974
(Thousands of Short Tons of Copper Content)


Net Ore Imports 38.7
Net Imports of Blister 206.1
Net Imports of Refined 177.2
Mine Production 1,597.0
Total Smelter Output 1,649.4
Total Refined Output 2,139.6
Total Refined Copper Supply 2,199.0
Crude Stocks & Other 63.8
Blister Stocks & Other 120.3
Refined Stocks & Other 118.8
Smelted From Scrap 79.5
Refined From Scrap 404.4
Total Copper Supply 3,167.0
Scrap Stocks & Other 3.0
Other Than Copper Base Scrap 21.1
Domestic Scrap 1,504.3
Copper Base Scrap 1,430.8
Scrap Recovered 1,451.9
Total Scrap Supply For Direct Consumption 968.0
Net Scrap Exports 70.5
Flows of ore, concentrate, and refined copper
Flows of scrap copper

Source: Compiled from Copper Development Association, Inc., *Copper Supply and Consumption, 1957–1975*, Tables 1 and 2.

Production of refined copper in the United States from all sources is detailed, in Table III-2, for 1974, 1975 and 1976, based on data from United States Bureau of Mines. We should underscore, again, the importance of domestically mined copper in the total United States refined copper supply stream and should note, secondarily, the fact that refined copper from scrap, produced both by refineries and by "secondary plants" (i.e., numerous small smelters of scrap copper), makes an important contribution to total United States refined copper supply.

Anticipating a more detailed discussion in Chapter VII-Demand, we should briefly note here that there are six major groups of consumers of refined copper and scrap: four copper semifabricating industries (i.e., wire mills, brass mills, foundries and powder mills), ingot makers and a group of "other industries" (e.g., chemicals, steel, aluminum). The one characteristic shared by the four semifabricating industries is that their basic input is copper. Their production technologies are almost completely different and their products are not substitutes or complements in any important ways.

The general task of the semifabricating industries is that of altering the shape of copper inputs. Wire mills and brass mills use mechanical means--drawing, rolling, cutting, etc.--to do this. Foundry products (plumbing fixtures, brass fittings, ship propellers) are cast. The final outputs of the semifabricating industries are semifabricated copper products (semis), which cover such products as electrical wire, pure and alloyed tube, sheet, castings and powder.

Small quantities of refined copper are used directly by chemical producers and small quantities of blister copper (from which refined copper is produced) are used by foundries; but these are minor exceptions to the use of refined copper, scrap copper, and copper alloy ingots by semifabricators.

D. THE STRUCTURE OF DOMESTIC COPPER MARKETS

1. Basic Considerations

Although some transactions in copper concentrates or blister do take place, mined copper is produced, sold, purchased and used mainly in refined form. Refined copper is marketed in regular or standard shapes consisting largely of wirebars, cathodes, ingots and ingot bars, cakes, slabs, and billets. Market transactions in refined copper, therefore, define the relevant copper market for the industry as a whole. Prices of blister or concentrates, whether they are actual or transfer prices, are derived from and depend upon refined copper prices, for example as a discount from the producers' price or as a premium over it depending upon overall market conditions. For analytical purposes,

TABLE III-2

PRODUCTION OF REFINED COPPER IN THE UNITED STATES, BY SOURCE, 1974-1976[a]

(thousands of short tons)

SOURCE	1974			1975			1976		
	TOTAL	Produced by:		TOTAL	Produced by:		TOTAL	Produced by:	
		Refineries	Secondary Plants[d]		Refineries	Secondary Plants[e]		Refineries	Secondary Plants[e]
TOTAL (primary and secondary)	2,151,566	2,067,177	84,389	1,787,864	1,714,258	73,606	1,911,668	1,825,874	85,794
Primary (new) refined copper produced in the United States	1,654,658	1,654,658	-	1,443,378	1,443,378	-	1,537,188	1,537,188	-
from domestic ores, as reported by refineries[b]	1,420,905	1,420,905	-	1,286,189	1,286,189	-	1,420,603	1,420,603	-
from foreign ores, matte, etc., as reported by refineries[b]	233,753	233,753	-	157,189	157,189	-	116,585	116,585	-
Secondary refined copper produced in the United States[c]	496,908	412,519	84,389	344,486	270,880	73,606	374,480	288,686	85,794
from new scrap	NA	229,328	NA	NA	139,230	NA	NA	144,215	NA
from old scrap	NA	183,191	NA	NA	131,650	NA	NA	144,471	NA

NOTES AND SOURCES:

[a] U.S. Bureau of Mines, Mineral Industry Surveys, "Copper in 1976" (April 15, 1977), p. 4.

[b] The separation of refined copper into metal of domestic and foreign origin is only approximate, as accurate separation is not possible at this stage of processing.

[c] Includes copper reported from foreign scrap.

[d] U.S. Bureau of Mines, 1974 Minerals Yearbook, Copper, Preprint, p. 29.

[e] U.S. Burea of Mines, Mineral Industry Surveys, "Copper in December 1976" (March 10, 1977), p. 3.

NA: Not available on a consistent basis from public sources.

it is generally accurate to think in terms of a unified market for copper, since the various forms in which refined copper or its equivalent are marketed are substitutable for each other at a relatively small cost.

The domestic copper industry has in the past been segmented into "primary" and "secondary" sectors on the basis of whether the copper product transacted in the market has originated from mined copper (virgin ore) or from scrap. By this definition, based on the source of copper, firms in the primary sector would be those which predominantly transform mined copper into refined copper, while firms in the secondary sector would be those which either predominantly process scrap copper into secondary refined copper or prepare it for direct consumption in the form of unrefined copper scrap.

For an economic analysis of the domestic copper industry, such a segmentation of the industry into primary and secondary sectors, on the basis of the source of the copper transacted in the market, is not very useful. First, the pricing behavior of the firms in the industry does not fall neatly into two non-overlapping categories based on whether the copper product transacted is derived from primary or secondary streams. Second, once refined, there is no physical difference between primary and secondary refined copper. Third, the major primary producers do often smelt and refine scrap in their operations, mostly for technological reasons, while at least one major secondary smelter/refiner has processed some blister from virgin ore. Further, there exist merchants, importers or firms which perform a combination of functions involving scrap, refined scrap or toll smelting/refining of mined copper.

We have hence segmented the domestic copper industry into "primary" and "outside" market segments for analytical purposes, on the basis of the pricing behavior of the firms on the sellers' side[1]. By this criterion, the primary sector consists of firms which sell the bulk of their refined copper output (mostly from mined copper but also including some refined from scrap) on the basis of a commonly-followed domestic producers price. Firms participating on the "outside" market, on the other hand, are those which sell their copper output regardless of its form (i.e., whether refined or scrap) and regardless of its origin (i.e., whether processed from mined copper--from domestic or foreign source--or refined from scrap) on the basis of one of several "outside market" prices. A detailed discussion of the pricing behavior of the firms in the copper industry is given in Chapter VIII-Prices.

Within the "outside" market, two broad segments can be distinguished. The first comprises a small number of firms processing mainly scrap into refined copper. The remainder of the secondary industry is comprised of a large number of firms--mostly small and individually owned--engaged in the collection, processing and consumption of unrefined scrap as well as in the trading of refined copper. These include scrap dealers, ingot makers, semifabricators, and merchants. Firms in this segment of the secondary market buy or sell unrefined scrap directly on the basis of quoted scrap prices.

These two segments of the "outside" market comprise two "workably competitive" markets which together represent a competitive fringe to the domestic primary producer market.

It should be noted, in this connection, that a "neat" definition of copper markets in terms of an unambiguously clear classification of the participating firms is extremely difficult. The "primary" and "outside" market designations used here for defining the structure of domestic copper markets, on the basis of the pricing behavior of the participating firms, should hence be taken as largely suggestive and not as definitive.

2. Firms in the Primary Copper Sector

The primary sector consists principally of the following firms which are vertically integrated to different degrees from mining to refining and further into semifabricating:

- Kennecott Copper Corporation;
- Phelps Dodge;
- The Anaconda Company (now a wholly-owned subsidiary of Atlantic Richfield Company--ARCO);
- Newmont Mining Corporation (of which Magma Copper Company is a wholly-owned subsidiary);
- Duval Corporation (a wholly-owned subsidiary of Pennzoil Company);
- Cyprus Mines, of which Cyprus Bagdad Copper Company, Cyprus Pima Mining Copper Company, Cyprus Bruce Copper and Zinc Company and Cyprus Johnson Copper Company are wholly-owned subsidiaries;
- Asarco Incorporated;
- The Copper Range Company, of which the White Pine Copper Company is a wholly-owned subsidiary;
- Inspiration Consolidated Copper Company;
- Cities Service Company;

- Ranchers Exploration and Development Corporation;
- Hecla Mining Company (in partnership with El Paso Natural Gas Company);
- Plus the following independent mining firms (among others): UV Industries, Inc.; Earth Resources Company; McAlester Fuel Company; Federal Resources Corporation; Eagle-Picher Industries, Inc.; Keystone Wallace Resources; and Micro Copper Corporation.

Detailed information on the primary producers is given in Tables III-3, III-4, and III-5 which respectively show mine production of recoverable copper (in 1973 and 1974), smelter capacity (year-end 1975), and refinery capacity (year-end 1974, 1975 and 1976) by firm.

The mine production of recoverable copper was the principal product of nearly 200 mines in 1972, as shown in Table III-1. In addition, copper is produced as a byproduct or coproduct by mostly lead and zinc mines. As indicated in Table III-3, the top six domestic copper mines are the Bingham Canyon (Kennecott, in Utah), Morenci (Phelps Dodge, Arizona), Tyrone (Phelps Dodge, New Mexico), the Berkeley Pit (Anaconda, Montana), and Superior (Magma, Arizona). In 1973, a peak year, each of these mines produced more than 100,000 short tons of copper (contained metal). The ore is beneficiated (crushed, ground and metal sulfides recovered by flotation) in mills that are located near the mines.

Most of the domestically mined copper is produced in five western states--Arizona, Utah, New Mexico, Montana and Nevada (refer to Table III-6). Over 80 percent of total United States mine production is located in Arizona, Utah and New Mexico taken together. Arizona alone accounts for well over half the total United States mine production of recoverable copper (about 63 percent in 1976).

As noted in the last chapter, mills are almost always located close to the mines to minimize transportation costs. The value of the concentrates is high enough to allow some flexibility in smelter location. With the major copper mines centered in the Western states, most of the smelting capacity is in that region. Still, most smelters are located near the mills which supply them or on tide water or rail head in order to receive concentrates from distant mills. Refineries can be located anywhere between smelters and fabricators, since the transportation costs for blister and refined copper are about the same.

Since Asarco, which is both a major primary producer and a large custom/toll smelter and refiner[2], has in the past held a somewhat anomalous position in the domestic copper industry, a brief digression may prove helpful in clarifying our treatment of it for analytical purposes.

TABLE III-3

MINE PRODUCTION OF RECOVERABLE COPPER IN THE UNITED STATES, 1973 and 1974[a]

Company and Mine	Location	Mine Type	Amount (Short tons)		Composition (%)[b]	
			1973	1974	1973	1974
Kennecott Copper Corporation			471,721	402,213	27.46	25.19
Chino	New Mexico	OP	67,836	60,557	3.95	3.79
Nevada	Arizona	OP	50,012	37,562	2.91	2.35
Ray Mines	Arizona	OP	98,908	74,764	5.76	4.68
Utah	Utah	OP	254,965	229,330	14.84	14.36
Phelps Dodge Corporation			319,358	280,211	18.59	17.55
Morenci	Arizona	OP	119,535	112,790	6.96	7.06
Tyrone	New Mexico	OP	104,011	97,030	6.05	6.08
Ajo (New Cornelia)	Arizona	OP	53,797	43,501	3.13	2.72
Bisbee (Copper Queen)	Arizona					
Lavender Pit		OP	19,387	11,833	1.13	0.74
Underground Mines		UG	22,628	15,057	1.32	0.94
The Anaconda Company			200,454	190,059	11.67	11.90
Twin Buttes (Anamax Mining Co., under equal partnership with Amax Inc.)	Arizona	OP	36,824[c]	20,071[c]	2.14	1.26
Berkeley Pit	Montana	OP	104,474	98,889	6.08	6.19
Anaconda Vein Mines (Leonard, Load Haul Dump, Mountain Con, Steward Mines)	Montana	UG	21,674	17,454	1.26	1.09
Continental East Pit	Montana	OP	1,647	15,676	0.01	0.98
Yerington	Nevada	OP	35,835	37,969	2.09	2.38
Newmont Mining Corporation			160,381	151,826	9.34	9.51
Magma Copper Co.[d]						
San Manuel	Arizona	UG	22,474	29,437	1.31	1.84
Superior	Arizona	UG	135,789	120,208	7.90	7.53
Idarado Mining Co.[e]						
Idarado Mine	Colorado	UG	2,118	2,181	0.12	0.14
Duval Corporation (Subsidiary of Pennzoil Co.)			131,214	131,843	7.64	8.26
Battle Mountain, Esperanza, Mineral Park	Nevada Arizona	OP	55,619	52,249	3.24	3.27
Sierrita	Arizona	OP	75,595	79,594	4.40	4.98
Cyprus Mines Corporation			110,390	103,353	6.43	6.47
Cyprus Pima Mining Co., Pima Mine	Arizona	OP	88,140	81,889	5.13	5.13
Cyprus Bagdad Copper Company, Bagdad Mine	Arizona	OP	19,152	18,379	1.12	1.15
Cyprus Bruce Copper and Zinc Co.	Arizona	UG	3,098	3,085	0.18	0.19
Asarco Incorporated			73,100	79,200	4.26	4.96
Mission	Arizona	OP	46,600	40,300	2.71	2.52
Silver Bell	Arizona	OP	23,800	23,500	1.39	1.47
San Xavier	Arizona	OP	2,700	5,900	0.16	0.37
Sacaton	Arizona	OP	-	9,500	-	0.59
White Pine Copper Company (Subsidiary of Copper Range Co.)						
White Pine	Michigan	UG	78,506	66,898	4.57	4.19
Inspiration Consolidated Copper Company			65,196	61,238	3.80	3.83
Christmas	Arizona	OP	9,508	6,698	0.55	0.42
Inspiration (Thornton, Live Oak, Red Hill)	Arizona	OP	51,332	49,700	2.99	3.11
Ox Hide	Arizona	OP	4,356	4,840	0.25	0.30
Cities Service Company			33,280	33,855	1.94	2.12
Copperhill	Tennessee	UG	4,025	970	0.24	0.06
Miami (Copper Cities, Diamond H, Pinto Valley)	Arizona	OP	29,255	32,885	1.70	2.06
Amax (Anamax Mining Co., under equal partnership with Anaconda)						
Twin Buttes	Arizona	OP	36,824[c]	20,071[c]	2.14	1.26
UV Industries, Incorporated						
Bayard Operations	New Mexico	OP	24,240	24,167	1.41	1.51
SUBTOTAL (of ABOVE COMPANIES)			1,704,664	1,544,934	99.23	96.74
OTHERS (Calculated Residually)[f]			13,276	52,068	0.73	3.26
TOTAL[g]			1,717,940	1,597,002	100.00	100.00

NOTES AND SOURCES: ACCOMPANYING TABLE III-3

[a] Individual company data have been obtained from the 1973 and 1974 corporate annual reports and from American Bureau of Metal Statistics, Inc. (ABMS), Nonferrous Metal Data 1974 and 1975.

[b] Sum of the components may slightly differ from the totals given due to rounding-off.

[c] One-half of total Anamax production.

[d] 100.0% owned by Newmont Mining Corporation.

[e] 80.1% owned by Newmont Mining Corporation.

[f] The "Other" category was calculated as the residual of the total less the subtotal for the individual companies reported above. This category includes, for example, Rancher's Exploration and Development Corporation, Earth Resources Company, El Paso Natural Gas Company--Hecla Mining Company, McAlester Fuel Company, Federal Resources Corporation, Eagle-Picher Industries Incorporated, Keystone Wallace Resources, Micro Copper Corporation and others.

[g] The total is obtained from U.S. Bureau of Mines, Mineral Industry Surveys, "Copper in 1974" (April 8, 1975) for 1973 data (p. 3) and "Copper in 1975" (March 26, 1976) for 1974 data (p. 3).

TABLE III-4

COPPER SMELTERS IN THE UNITED STATES AT THE END OF 1975

		Annual Capacity	
Company	Location	Short tons of material[a]	Short tons of product[b]
Asarco, Inc.	El Paso, Texas	576,000	100,000
Asarco, Inc.	Hayden, Arizona	960,000	180,000
Asarco, Inc.	Tacoma, Washington	600,000	100,000
The Anaconda Company	Anaconda, Montana	750,000	198,000[c]
Cities Service Company, Copperhill Operations	Copperhill, Tennessee	75,000	16,000
Inspiration Consolidated Copper Company	Miami, Arizona	450,000	150,000
Magma Copper Company (subsidiary of Newmont Copper Co.), San Manuel Division	San Manuel, Arizona	800,000	200,000
Kennecott Copper Corporation			
Nevada Mines Division	McGill, Nevada	400,000	78,000
Chino Mines Division	Hurley, New Mexico	400,000	80,000
Ray Mines Division	Hayden, Arizona	420,000	80,000
Utah Copper Division	Garfield, Utah	1,000,000	280,000[d]
Phelps Dodge Corporation[e]			
Douglas Smelter	Douglas, Arizona	700,000	90,000
Morenci Branch	Morenci, Arizona	900,000	196,000
New Cornelia Branch	Ajo, Arizona	250,000	77,000
SUBTOTAL		8,281,000	1,825,000
White Pine Copper Co. (subsidiary of Copper Range Company)	White Pine, Michigan	NA	85,000
TOTAL		-	1,910,000

NOTES AND SOURCES:

[a] American Bureau of Metal Statistics, Inc. (ABMS), Nonferrous Metal Data 1975, p. 29. Figures given represent short tons of "change" (i.e., material intake or "feed" for processing).

[b] Estimated, based on individual company annual reports, 10-K forms, telephone conversations with individual company/plant representatives, and data given in Engineering and Mining Journal (E/MJ), 1976 International Directory of Mining and Mineral Processing Operations. The figures given here represent annual productive capacity defined in terms of production or output (copper content).

[c] Upon completion of Anaconda's smelter modification program, this is expected to rise to 216,000 short tons per year (18,000 short tons per month).

These figures are exclusive of Anaconda's new Arbiter plant near Anaconda, Montana. At this plant, production commenced in October, 1974; it was temporarily shut down in July, 1975 and was reopened in August, 1976. The Arbiter plant is expected to have a capacity of approximately 36,000 short tons of cathode copper production per year.

See The Anaconda Company, Proxy Statement for a Special Meeting of Shareholders to be Held October 20, 1976, p. 71.

[d] Exclusive of modifications underway expected to expand the existing capacity.

[e] The figures given here for Phelps Dodge Corporation are exclusive of the company's new Hidalgo smelter, at Playas in Hidalgo County, New Mexico, which is the first copper smelter in the United States to use flash smelting process developed in Finland. The Hidalgo smelter, which started operations on July 1, 1976 and produced 37,944 short tons of copper anodes in 1976, is expected to have a productive capacity of 100,000 short tons per year.

TABLE III-5

UNITED STATES COPPER REFINERY CAPACITY AT YEAR-END 1974, 1975 AND 1976[a]
(annual capacity, short tons of refined copper production)

Company, Location	Type[b]	At end of 1974	At end of 1975	At end of 1976
PRIMARY PRODUCERS				
Anaconda		295,000	252,000	252,000
Great Falls, Montana	E	180,000	252,000	252,000
Raritan Copper Works, Perth Amboy, N.J.[c]	E	115,000	-	-
Asarco		642,000	744,000	576,000
Baltimore, Maryland[d]	E	318,000	-	-
Perth Amboy, N.J.[e]	E	168,000	168,000	-
Tacoma, Washington	E	156,000	156,000	156,000
Amarillo, Texas	E	-	420,000	420,000
Kennecott		565,000	565,000	565,000
Garfield, near Magna, Utah	E	186,000	186,000	186,000
Anne Arundel County, Maryland	E	276,000	276,000	276,000
Hurley, New Mexico	LF	103,000	103,000	103,000
Phelps Dodge		537,000	537,000	537,000
El Paso, Texas	E	420,000	420,000	420,000
El Paso, Texas	LF	25,000	25,000	25,000
Laurel Hill, L.I., N.Y.	E	72,000	72,000	72,000
Laurel Hill, L.I., N.Y.	LF	20,000	20,000	20,000
Magma (subsidiary of Newmont)		200,000	200,000	200,000
San Manuel, Arizona	E	200,000	200,000	200,000
White Pine (subsidiary of Copper Range)		90,000	90,000	90,000
White Pine, Michigan	LF	90,000	90,000	90,000
Inspiration		70,000	70,000	70,000
Inspiration, Arizona	E	70,000	70,000	70,000
SUBTOTAL		2,399,000	2,458,000	2,290,000
SECONDARY REFINERS				
United States Metals Refining Co. (a subsidiary of AMAX, Inc.) Carteret, N.J.	E, LF[f]	260,000	260,000	260,000
Cerro Copper and Brass, Div. of Cerro Corp., St. Louis, Mo.	E	44,000	44,000	44,000
Chemetco, Inc., Alton, Illinois	E	40,000	40,000	40,000
Reading Industries, Inc., Reading, Penn.	E	40,000[g]	40,000[g]	40,000[g]
Southwire Co., Carrollton, Ga.	E	65,000[h]	65,000[h]	65,000[h]
SUBTOTAL		449,000	449,000	449,000
TOTAL		2,848,000	2,907,000	2,739,000

NOTES AND SOURCES:

[a] Except otherwise noted, data for 1974 and 1975 are based on American Bureau of Metal Statistics, Inc., (ABMS), Nonferrous Metal Data for 1974 and 1975; data for 1976 are estimates based on miscellaneous sources, including individual company annual reports and 10-K forms filed with the Securities and Exchange Commission.

[b] E: Electrolytic; LF: Lake and fire refining.

[c] Permanently closed in May, 1975.

[d] Permanently closed in December, 1975.

[e] Permanently closed in March, 1976.

[f] Electrolytic: 175,000 short tons/yr.; Lake and fire refining: 85,000 short tons/yr.

[g] These figures differ substantially from those listed in ABMS (see Note "a" above); based on data given in Reading Industries, Inc., Form 10-K, for the fiscal year ended December 31, 1975, p. 6.

[h] These figures differ somewhat from those listed in ABMS (see Note "a" above); based on data given in Southwire Co., 1975 Annual Report, p. 12.

TABLE III-6

MINE PRODUCTION OF RECOVERABLE COPPER IN THE UNITED STATES, BY PRODUCING STATES, 1974-1976

(short tons; copper content)

State	1974			1975			1976		
	Amount	Rank	Percent	Amount	Rank	Percent	Amount	Rank	Percent
Arizona	852,650	1	53.5	813,211	1	57.5	1,012,660	1	62.8
California	200	13	-	344	13	-	366	12	-
Colorado	3,003	10	0.2	3,560	9	0.3	2,450	10	0.2
Idaho	3,108	9	0.2	3,192	10	0.2	3,200	9	0.2
Maine	1,525	12	0.1	2,024	11	0.1	1,890	11	0.1
Michigan	67,297	6	4.2	73,690	6	5.2	45,230	6	2.8
Missouri	12,473	7	0.8	14,258	7	1.0	10,705	8	0.7
Montana	133,675	4	8.4	87,959	4	6.2	105,525	4	6.5
Nevada	83,725	5	5.3	81,210	5	5.8	57,480	5	3.6
New Mexico	197,374	3	12.4	146,263	3	10.4	175,245	3	10.9
Tennessee	6,231	8	0.4	10,041	8	0.7	10,830	7	0.7
Utah	230,088	2	14.4	177,155	2	12.5	185,760	2	11.5
Other States[a]	2,241	11	0.1	459	12	-	-	-	-
Total	1,593,590		100.0	1,413,366		100.0	1,611,341		100.0

NOTES: [a] Includes Alaska, Oklahoma, Oregon, and Washington.

SOURCES: U.S. Bureau of Mines, Mineral Industry Surveys, "Copper in 1974" (April 8, 1975), p. 3 and "Copper in 1976" (April 15, 1977), p. 3.

Until recently, Asarco differed from other primary producers in four respects:

- The firm was historically not backward integrated into domestic mining and milling operations;
- Asarco processed a large amount of concentrate and/or blister on a toll basis;
- The company frequently used large volumes of scrap as inputs to its refinery operations;
- Asarco's output until 1967 was reportedly sold on the basis of its own "custom smelter" price, an outside market price which frequently deviated from the domestic producers price, the basis on which the primary producers marketed their output.

In recent years, however, Asarco has made significant expansions backward into mining and milling. Moreover, as far as the processing of concentrate or blister on a toll basis is concerned, Phelps Dodge and other producers have also carried out this function for independent producers. Asarco, in addition, has significantly increased the proportion of mined copper from its own mines used in its smelting and refining operations. Finally, and perhaps most importantly, since 1967 Asarco has followed the producers price quotations in setting the selling price for its own output. For all of these reasons, Asarco is included with the other primary producers.

3. Firms in the "Outside" Market Segment

The firms in the "outside" market segment, as defined by us in this report, consist of the secondary refiners plus many small, individually-owned firms (scrap dealers, ingot makers, semifabricators engaged in scrap processing for own-consumption and merchants who generally buy and sell copper outside the principal producer-consumer channels). The classification of these firms in terms of whether they sell refined copper (mostly from scrap, some from mined copper, imports) or unrefined scrap is difficult because of the diversity or multiplicity or functions performed by the latter group of firms.

While there are a number of secondary copper refiners, several of them integrated forward into captive fabricating facilities. Amax and Cerro (Cerro-Marmon Corporation, since its merger with The Marmon Group, Inc., on February 24, 1976) have been the two most important of these during most of the postwar period. These secondary refiners sell their product at prices (explicit prices if in the open market or implicit prices if intra-company transfers are involved) which are more reflective of current market prices for scrap than of refined copper prices quoted by the primary producers. They have been responsible for an average of 12 percent of total refined copper supplied in the United States each year between 1950-1974 and have held about 11 percent of domestic refinery capacity during this same period. Since 1971 three other refiners, Chemetco, Southwire, and Reading Industries, have gradually come on-stream with substantial secondary refining, and, in the case of Southwire, smelting capacity (refer to Table III-5 for data on secondary refinery capacity levels).

Amax is considered a secondary refiner because most of its copper refinery inputs are in the form of scrap and because it sells its output on the basis of its own individually-determined price which basically reflects prevailing prices on the outside market.

Amax, similar to Asarco, has integrated backward into domestic mining in recent years, and currently produces copper concentrates and electrowon copper at the Twin Buttes (Arizona) project through Anamax Mining Company, an equal partnership with The Anaconda Company. Also, Anamax and Asarco have entered into a general partnership known as the Eisenhower Mining Company to develop the Palo Verde copper deposit near Twin Buttes.

Cerro-Marmon and the other newer secondary refiners are all so classified on the basis that their inputs are mostly in the form of scrap, and imported blister in some cases. Although most, if not all, of their refined copper output is consumed in their own captive fabricating facilities rather than being sold on the outside market, they, in effect, must charge their own fabricating facilities an imputed price for their refined output reflecting the scrap price(s) prevailing on the "outside" market plus the incremental cost of refining[3]. In other words, similar to Amax, they are price-takers in an essentially competitive market.

It should be noted that not all of the output of these firms, for whomever produced, is necessarily marketed on the "outside" market prices. At the same time, their combined output does not necessarily cover all of the transactions on the "outside" market (i.e., the "outside" market also includes imports other than the sales of Noranda, a Canadian company, in the United States, as well as sales by merchants, scrap dealers, ingot makers and others--e.g., sales by semifabricators engaged in scrap processing and/or "secondary plants" which are numerous small smelters of scrap copper).

Further discussion of the participants on the "outside" market and their roles is given in Chapter VIII-Prices.

4. Domestic Copper Output by Primary and Secondary Producers

A fairly close approximation of how much of the domestically produced refined copper in a given year is transacted on the market at producers' prices can be made by performing a simple, four-step calculation (ignoring inventories): (a) estimate total refined copper output in the United States, in a given year, from all sources by all firms (e.g., 2,151.6 thousand short tons in 1974); (b) estimate total secondary refined copper output in the United States (e.g., 496.9 thousand short tons in 1974); (c) estimate how much of the total secondary refined output is produced by the primary producers and how much by the secondary smelters/refiners, respectively (e.g., in 1974, it is estimated that of the 496.9 thousand short tons, 382.1 thousand short tons produced by the secondary smelters/refiners and the remaining 114.9 thousand short tons by the primary producers); (d) subtract the secondary refined output of the secondary smelters/refiners from total domestic refined copper output (e.g., 2,151.6 thousand short tons minus 382.1 thousand short tons equals 1,769.5 thousand short tons), which yields an estimate of total primary refined copper output in the United States sold at producers' prices.

The results of such an analysis, based on a number of simplifying assumptions, are given in Tables III-7 and III-8.

Finally, Table III-9 shows estimates to total secondary copper produced in the United States which is directly consumed.

E. CONCENTRATION, INTEGRATION, ENTRY CONDITIONS AND STRUCTURAL CHANGES

The degree of concentration and vertical integration in an industry, as well as the existence of barriers to entry, are important considerations in analyzing pricing behavior of firms. Where concentration is low, there will normally be such a large number of firms and each individual firm's share of the market will be so small that no individual firm would be able to influence prices significantly (i.e., firms are entirely price-takers). Where concentration is high, the pricing and production decisions of any one firm will have some effect on the pricing and output of other firms in the relevant market; consequently, price-output determination by the firms will be interdependent.

TABLE III-7

ESTIMATED SECONDARY REFINED COPPER PRODUCED BY PRIMARY PRODUCERS AND SECONDARY PRODUCERS, 1960-1974

Year	Total Production of Refined Copper from Scrap	Copper Refined from Scrap by Secondary Producers	Copper Refined from Scrap by Primary Producers	Percentage of Copper Refined from Scrap by Secondary Producers (%)
	(thousands of short tons)			
1960	291.7	229.3	62.4	78.6%
1961	270.4	190.0	80.4	70.3
1962	289.7	195.1	94.6	67.4
1963	302.0	235.5	66.4	78.0
1964	351.1	240.1	111.0	68.4
1965	445.1	263.2	176.9	60.3
1966	491.3	277.5	213.8	56.5
1967	406.6	271.4	135.2	66.8
1968	416.6	273.6	143.0	65.7
1969	499.1	263.1	236.0	52.7
1970	511.6	251.7	259.9	49.2
1971	400.7	214.8	185.9	53.6
1972	423.2	252.2	171.0	59.6
1973	465.1	348.8	116.3	75.0
1974	496.9	382.1	114.9	76.9

SOURCE: U.S. Bureau of Mines, Minerals Year Book, 1960-1973; Mineral Industry Surveys, Copper Industry in December 1975, (March, 1976), p. 3.

TABLE III-8

REFINED COPPER PRODUCTION IN THE UNITED STATES, BY PRIMARY AND SECONDARY PRODUCERS, 1950-1974

(thousands of short tons)

Year	Total Refined Production	Primary Producer Refined	Secondary Producer Refined
1950	1446.4	1300.8	145.6
1951	1362.5	1247.2	115.3
1952	1320.5	1220.2	100.3
1953	1504.0	1345.6	158.4
1954	1418.4	1249.1	169.3
1955	1562.8	1355.4	207.4
1956	1687.8	1501.3	186.5
1957	1676.1	1467.4	208.7
1958	1579.5	1389.3	190.2
1959	1331.5	1087.9	243.6
1960	1794.6	1565.3	229.3
1961	1813.9	1623.9	190.0
1962	1884.5	1689.4	195.1
1963	1884.4	1648.9	235.5
1964	1990.4	1750.3	240.1
1965	2214.8	1946.6	268.2
1966	2183.3	1905.8	277.5
1967	1526.6	1255.2	271.4
1968	1839.0	1565.4	273.6
1969	2214.9	1951.8	263.1
1970	2242.7	1991.0	251.7
1971	1962.4	1747.6	214.8
1972	2258.5	2006.3	252.2
1973	2312.6	1963.8	348.8
1974	2151.6	1769.5	382.1

SOURCES: Based on Copper Development Association, Inc., Annual Data 1975, Copper Supply and Consumption, 1955-1974; Table III-2 (for 1974).

TABLE III-9

PRODUCTION OF SECONDARY COPPER IN THE UNITED STATES, REFINED AND UNREFINED RECOVERED FROM PURCHASED SCRAP, 1974-1976.

(thousands of short tons of copper content)

	1974	1975	1976
Total secondary copper produced in the United States[a]	1,344,320	971,965	1,106,000
recovered as unalloyed copper	513,308	355,512	374,000
recovered as alloys[b]	831,012	616,453	732,000
Less:			
Total refined copper produced from scrap in the United States[c]	496,908	344,486	374,480
Equals:			
Total secondary copper produced in the United States which is used directly	847,412	627,479	731,520

NOTES AND SOURCES:

[a] U.S. Bureau of Mines, Mineral Industry Surveys, "Copper in 1976" (April 15, 1977), p. 4. Includes copper recovered from both copper-base scrap and other than copper-base scrap.

[b] Includes copper in chemicals, as follows:
1974: 2,649
1975: 2,480
1976: Not available, estimate included.
Source: Ibid.

[c] Refer to Table III-2.

Next, the degree of vertical integration is important for two reasons. First, in an industry which is highly integrated, producers' material costs are somewhat insulated from the forces of market demand at intermediate stages of production. This does not mean that producers, in making pricing and output decisions, can ignore market forces, but rather than the relevant demand forces emanate from downstream markets. Second, economies of vertical integration or the existence of a high degree of integration in a particular market can constitute an effective barrier to entry into the industry.

The existence of barriers to entry into the industry is important since the absence of barriers to entry can mitigate the effect that a high degree of concentration would normally have on pricing and production behavior of the existing producers.

1. Industry Concentration

The United States copper industry is highly concentrated. In 1974, four firms--Kennecott, Phelps Dodge, Anaconda, and Newmont--accounted for 64 percent of total United States mine production. Eight firms, including these four plus Duval, Cyprus, Asarco and Copper Range, accounted for 88 percent of the total. Seven firms--Asarco, Kennecott, Phelps Dodge, Magma, Anaconda, Inspiration, and Copper Range--together represent virtually all of total United States smelter and primary refinery capacity.

2. Vertical Integration

Several of the domestic primary producers participate either directly or through subsidiaries in all five stages of production: mining, milling, smelting, refining and fabrication. The productive capacities, however, are not always matched between the different stages of production. Kennecott, the largest United States producer, is vertically integrated from mining through refining and, to a very small extent, further integrated downstream into fabricating through its wholly owned subsidiary, Chase Brass and Copper, which reportedly purchased 25 percent of its copper requirements in 1976 from Kennecott (constituting about 6.6 percent of Kennecott's copper sales in that year). Anaconda participates in fabrication through Anaconda American Brass and Anaconda Wire and Cable. These subsidiaries consume more copper than is produced by Anaconda. Phelps Dodge produces wire, wire rod and copper tube. These fabricating facilities consume about 30 percent more copper than the primary production of Phelps Dodge. Similarly, Cities Service owns New Haven Copper and Chester Cable; Copper Range owns Hussey Metals; Cyprus owns Cyprus Wire and Cable and El Paso Natural Gas (participant with Hecla Mining in the Lakeshore project) owns Narragansett Wire. While Asarco does not own fabricating capacity directly, it owns 33 percent of Revere.

Other producers are vertically integrated from mining through refining. These include producers of refined metal using smelting techniques (Magma/Newmont); using hydrometallurgical techniques (Ranchers) or both (Inspiration). Magma and Inspiration also produce semifabricated shapes.

The other producers do not participate fully in all stages of production. While Cities Service in Tennessee is integrated through smelting, its more significant production in Arizona is treated by Inspiration. Cyprus and Duval, except for experimental hydrometallurgical plants, use custom/toll smelters and refineries. Cyprus uses Phelps Dodge and Magma, and Duval uses Asarco. Similarly, Amax does not possess primary smelting and refining capacity. Amax's smelter and refinery in New Jersey treats mainly secondary materials. Its primary production is from Anamax, operated under equal partnership with Anaconda, by hydrometallurgical means. In addition, there are smaller independent mining firms, such as UV Industries, Earth Resources, Hecla Mining, McAlester Fuel, Federal Resources, Eagle-Picher, Keystone Wallace Resources, and Micro Copper, who use custom or toll smelting and refining services. The major custom and toll smelters and refiners are Asarco, Phelps Dodge, Inspiration and Anaconda. Others, such as Magma, process only minimal quantities.

3. Entry Conditions

Ease of entry into an industry is typically taken as a yardstick of the degree of competition prevailing in that industry. When entry into an industry (market) is free and easy, such an industry or market is defined as perfectly competitive. In a monopolistic market, entry is blockaded. In an oligopolistic market, characterized by relatively few sellers who are conscious of their interdependence, entry is not as easy as under perfect competition and not as insurmountable as under monopoly.

In his study Barriers to New Competition, J. S. Bain argued that the major barrier to entry into the copper industry was the high absolute cost of obtaining a sufficiently large ore body, although the existence of scale economies as well as high capital costs were important factors as well[4].

The importance of ore reserves as a barrier to entry is in part related to the competitive advantage derived from vertically integrated operations. A firm contemplating entry at the smelter and/or refinery stage must find some sources of concentrate supplies. A new entrant must either rely on the purchase of concentrate from a number of independent miners as has been done by the Japanese smelters or must bear the costs of discovering new ore reserves of sufficient size to support integrated operations which has been the experience in the United States.

Once having discovered new ore reserves, a new entrant would still be faced with extremely high capital costs for development of an integrated mine-through-refinery operation. We estimate that minimum efficient scale for an integrated operation would be a plant with a productive capacity of approximately 100,000 short tons of copper (metal content) on an annual basis. Assuming an estimated capital cost of $5,000-$6,000 per annual short tons of capacity (in constant 1974 dollars) to develop an integrated operation, the total minimum capital cost of an integrated operation would be in the neighborhood of $500-$600 million. Projects of this magnitude almost certainly will be undertaken only by large, well-established firms, or jointly by a group of such firms.

Entry into the copper indsutry has not been as difficult, however, at the mining and milling level; many smaller independent mining and milling facilities have been operating in the industry for years, supporting themselves through factors such as regional markets, lower processing costs due to richer ore bodies, or the use of regional smelters and refineries owned by the major producers for toll or custom smelting and refining of their output.

However, the significance of the entry by smaller mines in terms of their influence on primary producer behavior is difficult to assess. The output of these individual mines is usually an extremely small part of total supplies, and the life of such mines is frequently short. More importantly, the overall size of the independent mining sector relative to mining production by the primary producers has not significantly increased in the recent past, although the output of some of these smaller mines has gradually increased to an extent such that these mines have joined the ranks of the primary producers (e.g., Duval and Cyprus).

4. Major Structural Changes[5]

A discussion of industry concentration, vertical integration and entry conditions should not mask the fact that the United States copper industry has recorded significant structural changes during the last thirty years. In 1950, Kennecott, Phelps Dodge and Anaconda produced, within the United States, 713,000 short tons or 78 percent of the country's total mine output of 915,000 short tons. In 1973, a peak year, these same three firms accounted for 58 percent of total United States mine output of recoverable copper. Magma, which operated a small mine in Arizona in 1950 has developed into a major domestic producer. Duval, which mined no copper in 1950, is similarly now an important producer. Further, Asarco had operated no United States copper mines in 1950, later became a significant domestic producer.

In 1950, Anaconda and Phelps Dodge were the only two integrated United States producers with mines, smelters and refineries. By 1973, Kennecott had become an integrated producer through the construction or purchase of smelters and refineries. Asarco had integrated backward through the development of copper mines. Inspiration had become an integrated producer by purchasing a smelter and building a refinery. Magma had become an integrated producer by building a second smelter and by later building a refinery. The White Pine operation in Michigan became completely integrated from mining through refined production. Amax, meanwhile, has taken firm steps to integrate backward into mining in recent years, as already noted above.

Consequently, the United States copper industry appears decidedly more diverse and less concentrated today than it was thirty years ago. It is also quite likely far more interdependent or complex today in terms of custom/toll smelting/refining arrangements, as well as domestic and foreign joint investment arrangements.

CHAPTER III

NOTES

1. In the case of a few firms, there is some ambiguity concerning the type of copper input (e.g., mined copper or scrap) predominantly processed by these firms over the past three decades. Moreover, where firms process inputs of both blister and scrap, the specific proportions have often reportedly changed over time. In all such ambiguous cases, we have used pricing behavior as the overriding yardstick for classifying firms into either the primary or the "outside" market segments.

2. Custom smelting/refining: purchasing ores or concentrates from other producers for own-account smelting and refining. Toll smelting/refining: smelting and/or refining (ores, concentrates) for a fee and then returning the resulting metal to the mining company for marketing.

3. In terms of microeconomic theory, as price-takers the secondary refiners will maximize profit by producing refined copper until their marginal cost of producing an additional unit of output is just equal to the prevailing price in the market, in this case the outside market. If they charge their captive fabricators an imputed price less than the full market price, they will be foregoing revenues (by absorbing costs) which they could obtain by selling the copper on the outside.

4. See J. S. Bain, Barriers to New Competition (Cambridge, Massachusetts: Harvard University Press, 1956) and O. C. Herfindahl, Copper Costs and Prices: 1870-1957, Published for Resources for the Future (Baltimore: Johns Hopkins Press, 1959).

5. See Simon D. Strauss, Executive Vice President of Asarco, Inc., "Competition in the Nonferrous Metal Markets", presentation before the Annual Meeting of the American Institute of Mining, Metallurgical and Petroleum Engineers, Atlanta, Georgia, March 9, 1977.

IV. FINANCIAL CHARACTERISTICS OF THE UNITED STATES COPPER INDUSTRY AND THE PRINCIPAL COMPANIES

A. INTRODUCTION

In this chapter we present data on the operations of the principal companies which account for most of the primary copper production in the United States. We have in certain cases assembled data covering the decade 1964 through 1974, and in other cases have chosen the year 1974 for comparisons. Full data for later years were not available during the course of our work but became available after the report was finalized in draft form. We incorporate later information as appropriate and to the extent it was feasible to do so. In any event, the use of 1974 as the base and/or last year for much of the analysis is consistent with the calculations and perspective employed elsewhere throughout this study.

The remainder of this chapter is organized as follows: Section B contains an overview of the financial performance of the principal firms in the industry, based on comparisons of company financial and operating data. This is followed, in Section C, by an analysis of the significance of domestic sales and earnings in comparison with sales and earnings derived from foreign holdings, and some indication of those holdings. Next, Section D presents a review of the capital needs of the major firms in the industry and sources of capital. Finally, Section E contains a detailed examination of trends in debt and debt-equity ratios, the term structure of debt, and the extent of pollution control financing.

A detailed description of the activities of each of the major producing companies is provided in Appendix A which has been prepared for further reference.

In recent years, the United States copper industry has experienced modest growth in sales, low return on invested capital, eroding profit margins and higher debt, reflecting the combined pressure of inflation, higher cost of capital, increased capital requirements for environmental control and the worst recession during the postwar period.

Overall profitability for the copper producers, in terms of operating margin on sales, declined from about 23 percent in 1967 to 19 percent in 1974. Over the same period, profit margins for large industrial companies and manufacturers in general were rather stable. In terms of after-tax return on stockholders' equity, copper produders have shown a rate of return equal to the Federal Trade Commission (FTC) average for all manufacturing. However, the copper industry has been characterized by much greater volatility in its rate of return. This, in turn, stems from the cyclicality of the industry and fluctuations in copper prices. The financial performance of the companies suggests that firms in the industry are typically long-term profit maximizers, with an operative target rate of return on investment. Their pricing behavior, as discussed in Chapter VIII-Prices, is influenced by long-term competition from aluminum.

Capital expenditures by most companies increased sharply in recent years. A significant portion (i.e., about 25 percent) of the total industry capital expenditures over the period 1972-1975 has been for pollution abatement, mostly associated with SO_2 controls at smelters. About 60 percent of the total, however, represents investment in mining and milling capacity.

With capital expenditures increasing faster than internal cash generation (from earnings, depreciation, and deferred taxes), the cash-flow position of the companies deteriorated. Consequently, there has occurred in recent years a sharp increase in external financing. Over the last five years, overall debt has approximately doubled, while equity has increased significantly. Indeed, some companies are believed to have temporarily reached prudent limits to debt in their capital structure and await higher earnings and stock prices to restore balance and financing flexibility.

Domestic copper producers also participate in the production of other metals, both domestically and internationally, as a means of long-term diversification. While some copper companies are engaged in primary aluminum production and/or fabrication, others are normally involved in the production of lead and zinc. A few producers participate jointly in foreign copper mining companies, notably in Africa, Canada, and South America; these companies derive 20-25 percent of total sales and a higher percentage of their after-tax earnings from foreign operations. By-product recovery operations, especially for precious metals, and coproducts such as molybdenum, have been at times relatively significant to several companies; however, they appear to play a minor role in long-term investment decisions regarding industry growth and new copper production capacity, and at best play an imperceptible role in short-run price-output decisions.

Given access to ore bodies, the major barrier to entry into the industry is the size of capital requirements, where the long-term investment is highly risky in the face of a great deal of uncertainty surrounding copper prices. Because ore bodies frequently involve lead, zinc, silver and/or other metals of potential interest in addition to copper, and because of the riskiness of massive investments, the interests of the companies in nonferrous metals projects are frequently intertwined. Joint ventures, which constitute a means of diversification and pooling of risks, have consequently become quite common in the industry. Several major oil companies, which have considerable cash flow for investment, and which have been diversifying their own holdings of mineral resources, have, not surprisingly, recently taken an interest in developing copper properties or have made investments in some of the principal producing companies.

B. FINANCIAL PERFORMANCE

1. General

Table IV-1 presents a financial overview of the United States primary nonferrous metals industries for the most recent six-year period, based on Federal Trade Commission data compiled for Enterprise Standard Industry Classification Number 33. The picture has been one of modest growth in sales, low return on invested capital, eroding profit margins, and higher debt. Of course, this composite is the net effect of aluminum, copper, lead and zinc combined. Aluminum and lead-zinc subindustries have to be analyzed separately but in general the composite accurately reflects the pressures of the last five years of inflation, higher costs of capital, increased capital requirements for environmental controls and new capacity, and the worst recession in many years.

2. Copper Companies

a. Summary Comparisons

Tables IV-2 and IV-3 present selected financial statistics for the principal United States copper producers. These tables compare parameters which are believed to be particularly important from the standpoint of the impact analysis. More detailed summary financial data for each company are presented in Appendix A.

Table IV-2 indicates that:

- The industry is capital intensive, with typically more than one dollar of assets behind each dollar of annual sales.

- Inventory turnover is high.

- By-product gold and silver production can be quite important to the earnings of Asarco, Amax and Copper Range (silver); Kennecott and Newmont (gold). By the same token, industry joint-cost allocation and custom smelter contract practices can obscure the economics at various levels of production.

TABLE IV-1

FINANCIAL STATISTICS--PRIMARY NONFERROUS METALS CORPORATIONS, 1969-1974

(in billions of dollars)

	1969	1970	1971	1972	1973	1974
Sales	21.45	21.00	18.61	18.82	24.77	28.98
Net Before Federal Income Taxes	2.24	1.87	0.88	1.05	2.11	2.67
Net Income	1.42	1.29	0.62	0.69	1.34	2.04
% Net Income to Sales	6.6	6.1	3.3	3.7	6.9	7.0
Rate of Profit on Stockholders' Equity %						
Before Federal Income Taxes	20.7	10.3	4.8	9.0	21.6	12.7
After Federal Income Taxes	13.0	7.6	3.8	5.6	15.3	8.6
Cash Dividends	0.57	0.61	0.51	0.37	0.54	0.48
% Dividend to Net Income	40	47	82	54	40	24
Balance Sheet Data						
Cash and Government Securities	1.08	0.99	0.91	0.92	1.15	1.27
Receivables	2.94	2.83	2.32	2.88	3.27	3.14
Inventories	4.29	4.59	4.10	4.27	3.75	4.84
Total Current Assets	9.02	9.04	7.85	8.66	8.59	9.57
Bank Loans	0.64	0.73	0.53	0.64	0.38	0.59
Total Current Liabilities	3.86	4.13	3.28	3.69	3.77	4.62
Current Ratio	2.3-1	2.2-1	2.4-1	2.4-1	2.4-1	2.1-1
Cash Ratio	0.3-1	0.2-1	0.3-1	0.3-1	0.3-1	0.3-1
Long-term Debt	5.48	6.14	5.91	5.99	5.54	5.79

SOURCE: Federal Trade Commission and Standard and Poor's.

TABLE IV-2

SELECTED FINANCIAL STATISTICS FOR PRINCIPAL UNITED STATES COPPER PRODUCERS--1974 BASE

COMPANY (in order of copper production 1974)	Sales per dollar of assets	Total sales (thousands of dollars)	Value of Primary copper production @ 75¢/lb. (millions of dollars)	Value of primary copper as percent of company sales	Common stock (million shares)	1974 dollar earnings per share common	Year-end inventory turnover (times)	U.S. copper production-1974 (lbs. per share)	Gold production in troy ounces per share common	Silver production ounces per share	Aluminum production lbs. per share	Characteristic Growth Rate -Last 5 Years[a]		Effect of Δ 5¢/lb price of U.S. copper[k]
												Sales	Earnings share	
Kennecott	0.77	1,664	$603	36	33.2	5.08	11.0	24.2	.011	0.10	--	13.0%	3.5%	$1.21
Phelps Dodge	0.69	1,026	421	41	20.6	5.47	5.1	27.3	Nil	0.14	13.6[b]	9.5	8.0	1.36
Anaconda	0.86	1,673	285	17	22.0	4.83	7.0	17.3	Nil	.162	27.1	2.5	-5	0.87
Newmont Mining	0.49	548	225	41	24.6	4.55	4.0	12.2	.008	.008	—	15.5	6.5	0.61
Pennzoil (Duval)	0.6[c]	942	197	21	32.1	3.67	7.5[c]	8.2	Nil	0.04	—	32	29	0.41
Cyprus Mines	1.0	424	150	35	10.5	5.06	6.0	19.1[d]	Nil	Nil	—	26	12.5[e]	0.96
Amax	0.66	1,164	149[i]	13[j]	23.9	5.61	8.2	8.3[i]	.042	1.10[f]	8.5[g]	13[h]	10	0.41
Asarco	1.0	1,344	124	9	26.7	4.71	6.0	6.2	Nil	2.05[f]	--	11	6.5	0.31
Copper Range	0.91	169	101	60	2.34	7.66	5.6	57.3	Nil	0.21	--	13.5	0	2.87
Inspiration Consolidated	0.63	97	84	87	2.42	3.92	7.0	46.3	Nil	.06	—	12.5	10.5	2.31
Cities Service	1.0	2,806	61	2	26.9	7.58	10.0	3.0	Nil	Nil	—		12.6	0.15

ACCOMPANYING TABLE IV-2

NOTES: [a]As computed by Value Line Investment Survey (February 27, 1976), for the metals and mining companies and as computed by ADL for Cities Service and Pennzoil. Growth in earnings/share over the period 1964-1974 for the Fortune 500 largest industrial companies averaged 9.5%/year.

[b]Share of Conalco production.

[c]Excludes United Gas Pipe Line Company, which was spun off.

[d]Includes minority shares of Pima's production.

[e]Before effects of expropriation by Peru of Marcona subsidiary assets.

[f]Mostly refined under toll agreements. Asarco equity in mine production amounts to 0.3 oz. per share.

[g]50% share of Alumax production.

[h]Amax now reports sales on a restated basis to include Alumax, Inc. (1974 sales of $464 million) on an equity basis.

[i]Refined copper for own account, approximately 25% of which is derived from U.S. mines, 75% from scrap and/or foreign material.

[j]Actually 17% of 1974 sales, due to sale at higher prices.

[k]The figures presented here on a pre-tax basis, ceteris paribus, exclude foreign price change effects which could be important in some cases.

SOURCE: Arthur D. Little, Inc. estimates.

The information presented above has been obtained from company annual reports and SEC filings, statistical services, financial manuals, and other sources believed to be reliable, but its accuracy and completeness are not guaranteed.

While reasonable care has been taken in data compilation and presentation, we cannot guarantee absolute comparability from one company to the next, due to differences in the nature of earnings, and differences in accounting. However, to the best of our knowledge, the above data present an accurate and meaningful basis for selective comparisons.

TABLE IV-3

SUMMARY OF SALIENT FINANCIAL ASPECTS OF UNITED STATES COMPANIES

Company	Value of 1974 Production of Primary Copper @ 75¢/lb. (millions of dollars)	1971-1974 Average Operating Margin on Total Company Sales (percent)	Total Average Capital Spending 1972-1974 (million of dollars)	Level of Operating Profit @ 75¢/lb. Copper, Co. Average Margin Only on Primary (millions of dollars)	Employment Levels[c] Mining, Milling, Smelting and Refining	Long Term Dept (12/31/75) as Percent of Total Capitalization	Common Stock at 12/31/75 Book Value $/Share	Common Stock at 12/31/75 Market Value % Book
Amax	$149	15.1%	$ 227	22.5	1,500	27%	42.7	111
Anaconda	285	10.2	145	29.1	5,500	28[d]	54.8	31
Asarco	159[f]	6.7	101	10.7[f]	3,400	28	32.2	41
Cities Service	61	17.5[a]	370	10.7	2,000	32	60.5	64
Copper Range	101	13.4	6	13.5	2,800	23	44.9	41
Cyprus Mines	150	31.7	43	47.6	2,000	23[e]	29.4	74
Inspiration Consolidated	113[b]	24.4	29	27.6	2,200	26	35.1	59
Kennecott	603	19.0	187	114.6	11,000	21[d]	42.2	73
Newmont	225	29.9	48	67.3	4,400	27[e]	26.4	87
Pennzoil (Duval)	197	15.9	267	31.3	2,600	55[e]	15.5	125
Phelps Dodge	421	20.4	182	85.9	7,500	37	43.4	84

NOTES:

[a] Figure used in Standard and Poor's Copper Composite Average.

[b] Figure used is 1973 deliveries basis; 1974 figure not representative due to production difficulties.

[c] The employment level in U.S. primary copper production totals 45,000 for the above companies.

[d] Total capitalization includes capitalized lease obligations.

[e] Total capitalization includes minority interests.

[f] Based on total Asarco mine production, of which the domestic U.S. share accounts for 78 percent. Average earnings from primary metals sales were $44 million pre-tax. If prorated based on sales, copper would have accounted for $12.8 million.

SOURCE: Arthur D. Little, Inc. estimates.

The information presented above has been obtained from company annual reports and SEC filings, statistical services, financial manuals, and other sources believed to be reliable, but its accuracy and completeness are not guaranteed.

While reasonable care has been taken in data compilation and presentation, we cannot guarantee absolute comparability from one company to the next, due to differences in the nature of earnings, and differences in accounting. However, to the best of our knowledge, the above data present an accurate and meaningful basis for selective comparisons.

- A 5¢/per pound change in the price of copper has a major impact on Copper Range and Inspiration earnings per share. These two companies have the highest percentage refined copper sales to total company sales.

- Aluminum production is a major factor in Anaconda's and Phelps Dodge's earnings outlook.

Table IV-3 presents a company-by-company comparison of copper revenues, total company capital spending, normalized level of profit on primary copper production, employment, debt in total capitalization, and the common stock valuation. At year-end 1975, debt averaged about 30 percent of total capitalization, and equity was typically at a market price below book value.

b. Profitability

Table IV-4 presents a 10-year record of return on stockholders' equity by company. Table IV-5 compares the company data to the FTC average for all manufacturing companies. Because the FTC data and the company data are not necessarily on the same accounting basis (e.g., the latter are likely to be inflated by inventory profits to a lesser degree) and cover a period when wage and price control anomalies existed, it cannot be asserted that differences in the average rates of return observed are statistically significant. However, the indications are that the volatility of returns has been greater over the period for the copper companies--i.e., their business would appear to be riskier than the FTC average.

Table IV-6 indicates furthermore that profitability in the copper industry, in terms of operating margins on sales, has declined over the last ten years whereas that for industrials generally has been maintained.

3. Considerations Regarding Integrated Operations

a. Smelting and Refining

Eight of the eleven primary producers are integrated forward into smelting, eight have refineries, and seven are integrated through both smelting and refining stages of production. Table IV-7 presents the smelting and/or refining capacity for the principal companies. This represents nearly all of the United States capacity, except for secondary refined capacity as represented by Cerro Corporation, and other independent fabricators.

An important aspect of the primary copper (and also lead and zinc) industries is that traditionally the cost of smelting and refining has been small compared to the price of copper, and furthermore, these operations have been at a fixed and relatively low margin which is not very sensitive to the price of the finished product. This, in turn, means that the smelting and refining plants have been operated mainly

TABLE IV-4

OVERALL RATE OF RETURN: NET INCOME AS PERCENT OF NET WORTH
(percent)

Company	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
AMAX	18.9	16.9	13.0	13.1	12.5	13.7	8.9	10.1	12.5	15.8
(Tax Rate)	(25)	(21)	(19)	(22)	(28)	(23)	(20)	(27)	(30)	(27)
Anaconda	7.2	11.2	8.8	8.0	8.5	5.7	-30	13.6	8.3	19.5
(Tax Rate)	(50)	(49)	(57)	(54)	(54)	(11)	(Credit)	(4)	(24)	(34)
Asarco	14.6	17.7	13.3	12.5	15.5	13.1	6.8	7.2	14.7	14.6
(Tax Rate)	(NA)	(30)	(23)	(15)	(21)	(22)	(11)	(17)	(17)	(21)
Copper Range	12.4	11.4	0.8	11.5	15.9	8.9	- 3.4	- 2.5	10.0	15.0
(Tax Rate)	(24)	(22)	(45)	(21)	(19)	(29)	(Credit)	(Credit)	(37)	(28)
Cyprus Mines	10.9	12.6	13.1	13.7	13.6	14.4	13.4	12.8	15.4	17.2
(Tax Rate)	(30)	(27)	(17)	(23)	(31)	(26)	(35)	(20)	(31)	(36)
Inspiration Consolidated	13.3	12.1	6.0	11.6	24.1	27.1	12.5	15.8	16.7	10.4
(Tax Rate)	(22)	(25)	(10)	(14)	(43)	(33)	(28)	(27)	(4)	(14)
Kennecott	12.3	13.6	7.9	10.9	14.9	15.8	7.3	7.3	12.2	11.7
(Tax Rate)	(50)	(52)	(36)	(26)	(28)	(30)	(15)	(16)	(26)	(29)
Newmont	*	*	*	*	17.4	18.1	12.3	9.8	18.3	17.8
(Tax Rate)					(34)	(32)	(19)	(22)	(27)	(27)
Phelps Dodge	14.6	16.4	9.9	11.9	15.2	16.4	10.4	11.0	13.4	12.6
(Tax Rate)	(38)	(41)	(34)	(33)	(32)	(37)	(35)	(35)	(38)	(25)
Averages:										
Pre-Tax Returns	19.7	20.9	13.0	17.2	22.5	20.3	5.5	12.0	18.2	18.9
After Tax Returns	13.0	14.0	9.1	11.7	15.3	14.8	4.2	9.5	13.5	13.8
Tax Rate	34	33	30	32	32	27	23	21	26	27

NOTES: NA: Not Available.
*Newmont became an operating company with the merger of Magma Copper in 1969.

TABLE IV-5

RATES OF RETURN ON STOCKHOLDERS' EQUITY
(percent)

Years	FTC All Manufacturing		Average of Major Copper Companies		Inflation Rate[b]
	Pre-Tax	After Tax	Pre-Tax	After Tax	
1965	21.9	13.0	19.7	13.0	1.8
1966	22.5	13.5	20.9	14.0	2.7
1967	19.3	11.7	13.0	9.1	3.5
1968	20.8	12.1	17.2	11.7	3.3
1969	20.1	11.5	22.5	15.3	4.9
1970	15.7	9.3	20.3	14.8	5.5
1971	16.5	9.7	5.5	4.2	4.4
1972	18.4	10.6	12.0	9.5	3.6
1973	21.8	13.1[a]	18.2	13.5	5.5
1974	23.4	14.9[a]	18.9	13.8	10.4
Averages	20.0	11.9	16.8	11.9	NA
Standard Deviation (%)	2.6(13)	1.8(15)	5.2(31)	3.4(29)	NA

NOTES: [a] Fortune 500 all-industry median was 12.4% in 1973 and 13.6% in 1974.

[b] GNP Implicit Deflatory, (1958 = 100).
NA: Not Available.

SOURCES: Federal Trade Commission, Division of Financial Statistics, Quarterly Financial Report for Manufacturing, Mining, and Trade Corporations, 1975 eds.; and Arthur D. Little, Inc.

TABLE IV-6

TRENDS IN OPERATING PROFIT MARGIN
(percent of sales)

Year	Large Industrial Companies[a]	Major Copper Companies[b]
1964	15.9	22.7
1965	16.2	26.5
1966	16.4	29.3
1967	15.5	23.9
1968	15.8	22.9
1969	15.4	27.8
1970	14.5	23.4
1971	14.6	15.5
1972	15.0	16.6
1973	15.8	19.1
1974	15.4	18.7

NOTES AND SOURCES: [a] Standard and Poor's composite data, 425 industrials.

[b] Standard and Poor's composite data, based on Anaconda, Copper Range, Inspiration Consolidated, Kennecott Copper, Newmont Mining, and Phelps Dodge.

TABLE IV-7

PRINCIPAL UNITED STATES COPPER SMELTING AND REFINING--1974

	Smelter Capacity			Refining Capacities		
Company	Thousand Tons	Percent of Total	Rank	Thousand Tons	Percent of Total	Rank
Anaconda	210	11	(4)	295[a]	11	(4)
Asarco	380	19	(3)	630[b]	23	(2)
Inspiration Consolidated	150	8	(6)	72	3	(8)
Kennecott	508	26	(1)	639	23	(1)
Newmont (Magma)	200	10	(5)	200	7	(6)
Phelps Dodge	402[c]	21	(2)	544	20	(3)
Copper Range[e]	85	4	(7)	90	3	(7)
AMAX[f]	-	-	(9)	250[d]	9	(5)
Cities Service	15	1	(8)	-	-	(9)
	1,950	100%		2,720	100%	

NOTES:

[a] New Jersey facility shut down in 1975, when Montana facility expanded capacity by38%.

[b] Baltimore refinery closed down in December 1975. Perth Amboy, New Jersey facility was scheduled to close down in 1976. New refinery in Amarillo, Texas came on-stream in mid-1975 with rated year-end capacity of approximately 215,000 short tons/year (50% of planned total for Amarillo).

[c] New smelter at Hidalgo, New Mexico, which was scheduled for operation in 1976, is expected to add capacity estimated at 100 thousand short tons/year or more, assuming continued operation of the three existing smelters.

[d] Smelter-refinery complex as estimated by ADL.

[e] Lake and fire-refined.

[f] Oriented to custom, foreign blister scrap.

as service operations in the conversion of concentrate into usable metal and alloys. In smelter and refinery contracts, changes in price of the primary metal are typically reflected back to the mine and hence affect directly the value of the concentrate. Any increase in smelting or refining costs generally cannot be "absorbed" by the smelter or refinery for this reason but has to be largely passed backward to the mines.

In the case of producers integrated from mining through smelting and refining, a cathode or wirebar may be the first product that is actually sold. The internal transfer price of the concentrates is usually calculated on the basis of the primary metal price, thus, any fluctuations in the primary metal price are again reflected back to the mine and have a major influence on the mine profitability[1]. Any change in wirebar price affects the concentrate value directly in custom smelting contracts, and the smelter and refinery margins remain unchanged.

b. The "Struggle Between Integrated and Independent Fabricators"

Although this study extends only through the refined copper stage of production, we cannot overlook the fact that several large primary producers are vertically integrated into fabricated products (wire and cable, tubing, sheet, and brass mill products), and there is an interplay in the market place between supply and price of new refined copper and the role of copper scrap in the fabricating industries.

Refined copper is fabricated into higher value, intermediate, and finished products by wire mills and brass mills, the former accounting for about 46 percent of United States consumption, and the latter about 40 percent. As stated elsewhere, the balance of consumption is accounted for by foundries, ingot-makers, and powdered metal usage. Overall, 40 percent or more of the brass mills' copper requirements are typically supplied by scrap materials.

The manufacturing divisions, subsidiaries, and affiliates of the major primary copper producers are belived to account for roughly 35 to 55 percent of total fabricating capacity. Of the three major producers, Anaconda appears to consume the highest percentage of its own copper, Phelps Dodge the next highest and Kennecott the least. Some individual company data are provided in Appendix A. The vagaries of the market from year-to-year, and the fact that the companies buy and sell to and from each other, complicates the picture. From a financial standpoint, the conventional distinction made between the integrated producers and the independent fabricators[2] such as Cerro Corporation, General Cable, Reading Industries, and Triangle Industries is best expressed by the following comments from Standard and Poor's Corporation in its 1975 Nonferrous Metals Survey:

> "For--integrated companies, this final production stage has traditionally served as an outlet for the primary copper produced. Thus, such companies have typically endeavored to maintain low prices on fabricated products, relying on the sale of primary metal for the bulk of their profits".

The largest expense for most independent fabriactors is the cost of copper; thus profitability depends substantially on the fabricators' mark-up or spread. As a result, again quoting Standard & Poor's,

> "there is often a struggle occurring the market--The integrated producers seek to keep product prices on fabrications low enough to boost demand and provide an expanding market for more profitable primary and refined output, while the independent fabricators strive to raise product prices and margins".

Both groups generally prospered in the demand crunch--high price environment of 1974; but the independents suffered less in the recession--low price environment of 1975, benefiting from the lower raw material costs. The integrated producers, with high fixed costs, suffered reduced operating rates as well as reduced prices, and reported substantial sales and earnings declines.

The subject of integrated versus independent producers is, we believe, quite a bit more involved than this, as might be inferred from various legal actions which have occurred or have been underway now for sometime, and which appear to relate at least in part to the operation of the United States two-price system (see Chapter VIII)[3].

More specifically, as has been stated in the "Notes to the Financial Statements" of the major producers, in 1970, Triangle Industries, Inc., instituted an action in the United States District Court for the Eastern District of Pennsylvania against Asarco, Anaconda, Cerro Corporation, Kennecott, and Phelps Dodge, alleging various violations of the Federal antitrust laws and seeking treble damages and divestiture by these producers of their copper fabricating facilities, and other relief. Reading Industries, Inc. subsequently filed a similar suit, and these actions were transferred to the United States District Court for the Southern District of New York, and have been in pre-trial discovery stage. Counterclaims were filed by some of the defendants. Cerro filed briefs and motions for dismissal, claiming it was not a United States producer. Asarco and Triangle subsequently agreed to have Asarco supply Triangle with copper under long-term contract, and Triangle withdrew its complaint against Asarco.

Over the period 1972-1975, the Antitrust Division of the United States Department of Justice was conducting a grand jury investigation of the copper industry in the United States generally. The primary producers were served with subpoenas requiring production of documents and information relating to copper prices since 1951; and exploration, development, smelting and refining activities since 1955. In 1974, the jurisdiction of this investigation was also transferred to the United States District Court for the Southern District of New York; we understand that the term of this Grand Jury expired in 1975.

The outcome of these actions should clarify the status of vertical integration in the copper industry. However, because of the nature and extent of our study, further treatment of these issues was beyond our scope, and would at best be speculative. Our analyses then necessarily have been based on the industry "as is", and as we and others outside may observe it.

C. DOMESTIC VERSUS FOREIGN SALES AND EARNINGS OF NONFERROUS METALS COMPANIES

1. General

Estimates of foreign and domestic sales and earnings from nonferrous metals operations are exhibited in Table IV-8. Notes and comments are provided in the table. This information is based on or computed from 1974 data presented in company annual reports and reports to the SEC. Very few companies reported foreign earnings in a straightforward manner, and even where information was given, it was often somewhat ambiguous. Thus, while reasonable care was taken in compiling this data and presenting it in a consistent fashion, we do not guarantee its absolute accuracy or comparability because of variations in accounting from company-to-company. The reader is referred to Appendix A for more details on each company.

Of the nine major primary copper producers listed, there is considerable variation in the percentage of earnings accounted for by foreign operations:

- Copper Range has a very small percentage of foreign sales revenues and earnings. Inspiration did not report any at all.

- Anaconda did not indicate net foreign sales, but reported $115 million in 1974 sales from Anaconda Canada Ltd. The net equity of nonconsolidated foreign affiliates abroad contributed to 13.5 percent of its total after-tax earnings.

- Kennecott indicated that 16 percent of sales were derived from customers abroad, producing 16 percent of earnings after tax.

- Phelps Dodge had foreign sales as percent of total sales revenue equal to 2 percent or less and foreign earnings after tax equal to 4 percent or less of total earnings.

- Amax's, Asarco's and Newmont's foreign sales are 20 to 25 percent of total sales, and their foreign after-tax earnings as percent of total after tax earnings ranges from about 30 percent for Newmont and Amax to over 60 percent in the case of Asarco.

2. Principal Participation and Joint Holdings

Foreign operations of United States copper companies often involve participation with others in ventures and joint holdings of foreign producers' companies.

The following tabulation indicates the principal participations in joint holdings of the major United States companies in copper production as of 1975.

Producer and Loaction	1974 Copper Production (tons)	Participations
Southern Peru Copper Corporation (Peru)	133,000	Asarco--51 percent Cerro Corporation--22.3 percent Phelps Dodge--16 percent Newmont--10.3 percent
ROAN Consolidated Mines (Zambia)	304,000	Amax--20 percent Zambian Government--51 percent
Granduc (British Columbia, Canada)	31,900	Leased 50 percent each by Asarco and Newmont, with Newmont operating
O'okiep Copper Company (South Africa)	35,600	Amax--17.0 percent Newmont--57.5 percent
Mount Isa Mines (Australia)	175,000	Asarco--49 percent
Tsumeb Corporation Ltd. (South West Africa)	24,700	Amax--29.6 percent Newmont--29.2 percent
Subtotal above (Outside U.S.A.)	750,000	
Anamax Mining (Arizona)	45,500	Amax--50 percent Anaconda--50 percent

The results of the operations of nonconsolidated foreign affiliates and associated companies are typically reported in terms of equity in such companies' earnings, which includes any cash dividends paid to the United States owners.

3. The Hazards of Foreign Investments

Extraordinary losses, as discussed in the financial reports of the major nonferrous metals mining companies, illustrate the risk of foreign holdings today. Indeed, the last several years would suggest the related write-offs are "ordinary" and not "extraordinary" losses in the course of business--as the panorama of nationalizations in Chile, Peru, Mexico, and Africa unfolds. In most cases, Overseas Private Investment Corporation insurance was available to cover much of the loss. But this is phasing out.

While foreign sales are considered subject to greater uncertainties--depending on the location of foreign subsidiaries and/or affiliates, expropriation, currency fluctuations, export and import restrictions, exchange restrictions, and other factors--the percentage of income before taxes on income from foreign sales revenues has generally been greater than that realized on consolidated total sales and operating revenues and hence on domestic operations. When the companies' share of dividends and/or equity in foreign affiliates' earnings is added to earnings from direct foreign operations, the fraction of foreign after tax earnings to total after tax earnings rises significantly. The greater profitability of foreign operations in 1974, on an after-tax basis, is indicated in Table IV-8. A higher return of course, is consistent with the notion of higher risk.

D. INDUSTRY FINANCING--CAPITAL NEEDS AND CAPITAL SOURCES

1. Ownership Patterns

The subject of industry financing logically should begin with an examination of the nature of the producing firms and their historical record with respect to capital spending, internal cash generation, and their pattern of external financing. The principal producers of copper are publicly-owned companies whose shares are traded on the New York Stock Exchange (and some on the regional exchanges). The aggregate book value of their total corporate assets was approximately $17 billion, and the market value of their common stocks totalled approximately half this (i.e., $8 billion) at year-end 1975.

We have not made a detailed study to determine the major shareholders of these companies. However, in view of several major recent proposed changes in ownership which have been widely publicized, we shall review briefly the pattern which has emerged and offer such comments as seem appropriate.

TABLE IV-8

1974 DOMESTIC SALES AND EARNINGS FROM NONFERROUS METAL OPERATIONS AND FOREIGN SALES AND EARNINGS--AS COMPARED TO TOTAL EARNINGS

Company	Sales from Domestic Nonferrous Metals Plants $ (millions)	Earnings From Domestic NFM Operations $ (millions)	Foreign Sales as Percent of Total Sales Revenues	Foreign Earnings (After Tax) $ (millions)	Foreign Earnings (After Tax) As Percent of Total
Asarco	$1,260.1	$ 89.7	23.2%	$ 93.4	67%
Amax	607.0	95.0[b]	18.0	62.07[a,c]	30.6[a,c]
Anaconda	1,567.3[d]	173.0[e]	11.0 Est.	14.4[g]	13.5[h]
Cyprus Mines	279.0[i]	82.7[j]	28.0	52.7[a]	37[a] 42[j]
Copper Range	166.6	28.3	10.0	N.A.[f]	N.A.
Inspiration Consolidated	97.1[k]	9.91[k]	nil	nil	nil
Kennecott	999.56[l]	248.8[l]	16.0	27.0[m]	16[m]
Newmont	301.2	70.7	25.0	37.8	30
Phelps Dodge	1,026.1	138.3	<1.0	1.524[n]	1.4

NOTES:

[a] Indicates before taxes.

[b] Includes $19 million equity in Alumax.

[c] Twenty percent of Amax earnings from operations before income taxes, exploration and unallocated corporate expenses were derived from its operations outside of the United States, primarily in Australia, Western Europe, Japan, Zambia, and Canada. In addition, approximately 9% of its income before taxes and extraordinary items was derived from dividends from foreign investments, primarily in Africa.

Applicable foreign earnings from operations, excluding exploration and unallocated corporate expenses were $43.5 million in 1974; $6.45 million of foreign exchange gains were included in 1974 earnings. Trading income, consisting primarily of profits on copper and silver transactions, was $12.5 million in 1974 (based on sales of $32 million, and pre-tax of $20 million) and is included in earnings from operations.

[d] Sales 93.7% of net sales--i.e., excludes sales between divisions, uranium oxide sales, etc.

[e] Total operating earnings shown.

[f] N.A.: Not available.

[g] Anaconda's equity in net income of affiliated companies in Mexico and Brazil accounted for $14.1 million in 1974. These foreign affiliated companies' contributions, after all applicable taxes, amounted to $10.8 million or 10.1%. Anaconda also received $5.45 million of interest from Chilean investments, which after tax of 34% (effective 1974 rate) was $3.6 million.

[h] Based on net after taxes before extraordinary income.

There was an extraordinary item which contributed $140.37 million to net income which involved settlement on the 1971 expropriation loss with the Government of Chile. If this item is considered, then 62.6% of total 1974 net income--i.e., $247.1 million, including the extraordinary item, was related to foreign activities.

[i] Includes manufacturing and nonferrous metals. Manufacturing includes copper and aluminum wire and cable, and some steel conduit and specialty steels.

[j] After tax basis estimated excluding minority interests. See separate material on Cyprus in statistical appendix.

[k] Includes interest income.

[l] Total metal and metal product sales were $1,160.1 million, out of total sales revenues of $1,664.2 million. Of these metal and metal products sales, $999.56 million were of nonferrous metals and products. Reports do not state amount attributable to United States. Earnings show total before tax earnings from metal and metal products operations, including items that are not nonferrous.

[m] Kennecott income derived from foreign sources before extraordinary credit represented about 16% of 1974 consolidated income before extraordinary credit. In addition to this $27 million, the company had an extraordinary credit (net of tax effect) of $42.3 million related to compensation from Chile for a 1971 expropriation of property. If the credit and net foreign sources ($69.3 million) are considered as percent of net income after tax and the extraordinary item, the percent from foreign sources was about one-third of 1974 total net income.

[n] Reported $1.52 million dividends included in reported earnings from foreign manufacturing interests abroad.

a. Asarco, Kennecott, Newmont and Phelps Dodge

Shares are widely held, as are Cities Service and Pennzoil.

b. Amax-Copper Range-Lousiana Land

For a number of years Amax held a 20 percent equity position in Copper Range. In late 1974, an agreement in principle was reached between the companies to merge Copper Range into Amax. In 1975, the Department of Justice sued to block the merger on antitrust grounds. Also in 1975, Amax sold a block of its stock to Standard Oil of California, which now holds approximately 20 percent interest in Amax. An additional 12 percent is held by Selection Trust Ltd. (Selection Trust Ltd., a diversified mining and financing company primarily concerned with minerals development, is affiliated with Charter Consolidated, Ltd., in London, which in turn is prominently identified with such companies as Rio Tinto Zinc Corporation, Ltd., and Anglo-American Group companies).

Amax stated that if consummated, the proposed acquisition would enable Amax to develop a portion of the Michigan copper deposits it had under lease near the Copper Range holdings. The proven ore reserves in Michigan that would have been mineable upon the acquisition would have totaled 121 million tons with an average grade, fully diluted, of 1.20 percent copper. Of this total, 18 million tons were under lease by Amax.

Subsequently, shareholders of Copper Range approved, over the opposition of Amax, the merger of their company into Louisiana Land and Exploration Company, in an exchange of stock valuing Copper Range stock at $21.45 per share. (This was well below its book value and substantially below asset replacement costs).

c. Cyprus Mines--Pima

A major shareholder block in the case of Cyprus Mines is the family of H. Mudd, who, together with associates, represent about 31.5 percent of the voting power.

Cyprus consolidates the operations of Pima Mining Company--the 7th. largest United States copper producer--in its financial statements. Cyprus owns 50.04 percent of Pima's stock. The balance is split between Union Oil and Utah International (now a part of General Electric Company).

d. Pennzoil--Duval

Duval is now a wholly-owned subsidiary of Pennzoil Company. Pennzoil got into the copper business via its 1968 merger with United Gas Corporation, of which Duval was a subsidiary. Duval is the fifth largest producer.

e. Inspiration Consolidated--Anaconda--Crane et. al.

In early 1975, Crane Company, through a subsidiary, acquired 5.5 percent of Inspiration's stock, and subsequently made a bid to obtain control of Inspiration. Anaconda had for some time held 27.6 percent of Inspiration's common stock and was its largest stockholder. Anaconda did not exercise control over Inspiration, but, agreeing with the management of Inspiration, voted to permit the sale of a substantial block to the Anglo-American Group of South Africa (Hudson Bay Mining, Anglo-American Corporation, et. al.) thus precluding Crane's attempt to take control. Anaconda now owns 20.4 percent, and the Anglo-American Group 30 percent of Inspiration's stock.

Later in 1975, Crane made a tender offer for 23 percent of Anaconda's shares. Anaconda's management was opposed to the offer. Shortly thereafter, Tenneco proposed a merger of Anaconda through an exchange of securities, and Anaconda's Board approved. But, in early 1976, Atlantic Richfield (ARCO) made a cash offer for 27 percent of Anaconda, with an agreement with Crane Company, giving ARCO a right of first refusal on Crane's holdings (then actually about 19 percent) for a stipulated period. ARCO and Anaconda subsequently agreed to merge Anaconda with ARCO and the merger has now been consummated.

f. Participation of Oil Companies

The recent Louisiana Land interest in Copper Range marks the sixth[4,5] significant oil company venture into United States primary copper production, via acquisition of operating interests. The others were, as indicated above, ARCO (1976), Union Oil, Cities Service, (1963), Pennzoil (1968), and Standard Oil of California (1975). The latter was indirectly, through Amax, and appeared to be focused on Amax's substantial interests in coal. (It is the fourth largest producer).

We believe it is not yet appropriate to attempt generalization from the foregoing. There are many other examples of oil companies diversifying their interests in natural resources-based businesses, just as there are many examples of nonferrous metals companies diversifying into coal, oil, and gas. We would expect that in at least several important cases, the provisions of the United States tax laws were an incentive.

2. Capital Needs versus Internal Sources

In its 1975 Survey of capital requirements at nonfinancial corporations, Business Week concluded that United States corporations in general were in the throes of a capital crunch which showed no signs of abating. (Those conclusions were based on data supplied by another McGraw-Hill group, the IMS subsidiary of Standard & Poor's Corporation). New outlays for the plant and equipment grew nearly twice as fast as common equity over the period 1969-1974, and internal cash generation fell far short of requirements (including dividends to shareholders). On average, 78 percent of the growth needs of large United States companies during the 1969-1974 period were satisfied through internal cash flow generation, with increased short-term and long-term debt sale of new equity making up the difference.

Table IV-9 compares the data for the major copper-producing companies. Table IV-10 shows actual average capital expenditures, the typically higher 1974 levels, and the expenditure rate in comparison to depreciation charges. Table IV-11 summarizes the estimated capital expenditures made on primary copper production only; and the amount of this for pollution control. Copper Range and Cyprus Mines covered most of their requirements from internally-generated funds. In fact, Copper Range's and Cyrpus' debt was only slightly higher at the end of 1974 than five years earlier, and debt-to-equity ratio remained about the same.

Among the other companies, debt-to-equity ratio typically increased. However, it is difficult to generalize; and the analysis must proceed on a specific, case-by-case basis, since the accounting for foreign government interventions in company operations (noticeably in Chile, Peru, and Zambia), and the effect of acquisitions and spin-offs on consolidated financial statements must be evaluated.

3. Equity Capital

a. Stock Prices

Figure IV-1 indicates the pattern of stock price changes for the major copper producers versus other metals stock groups and the Standard & Poor's Industrial Stock Composite. The extreme volatility over the recent period has important implications in regard to incremental cost of capital, suggesting that investors would normally demand a substantial risk premium on new equity offerings.

b. Price-to-Earnings Ratios (P/E's)

In general, P/E ratios of industrial issues have declined over the last ten years (1965-1975), from an average of about seventeen, to about ten recently. Analysts think of the copper industry as cyclical. For analytical purposes, their condition may be approximated by a model where earnings have zero growth or near-zero growth, e.g., a mature durable goods industry demand function and high payout of real earnings as dividends to stockholders. For a firm with zero or nearly

TABLE IV-9

INDICATORS OF THE NEED FOR CAPITAL FUNDS

Company	5-Yr Growth in Plant Equipment %	5-Yr Cash Flow as % of Total Growth Needs
Amax	102%	53%
Asarco	97	78
Anaconda	43	61
Cities Service	30*	72
Copper Range	38*	94*
Cyprus Mines	[a]	96
Inspiration Consolidated	192*	64*
Kennecott	47	83
Newmont Mining	[b]	76
Phelps Dodge	92	62
Pennzoil Co.	15	57[c]

NOTES: [a] Not available for purposes of comparison. The 442% indicated reflects IMS/Cyprus method of reporting, accounting, and restating for consolidation of subsidiaries over the period in question.

[b] Not meaningful for purposes of comparison, due to large investment holdings.

[c] Capital Expenditures net of retirement and disposals in some years.

*SOURCE: Arthur D. Little, Inc. All other figures are as presented by Business Week's Capital Survey, September 22, 1975.

TABLE IV-10

THE PATTERN OF CAPITAL EXPENDITURES AND DEPRECIATION CHARGES

Company	Reported Capital Expenditures -- Gross $MM		1970-74 Average Capital Expenditures as Percent Gross Plant	Depreciation Rate 1974-% Gross Plant
	Average 1972-74	1974		
Amax	227	338	17.8%	3.3%
Anaconda	144	194	7.4	2.8
Asarco	101	138	13.7	4.6
Copper Range	6	7.5	4.8	4.4
Cities Service	370	447	10.8	3.9
Cyprus Mines	43	67	11.6	5.9
Inspiration	29	18.8	13.7	5.7
Kennecott	187	218	9.7	4.3
Newmont	48	56	12.1	4.2
Pennzoil	267	279	11.0	5.4
Phelps Dodge	182	275	11.9	2.4
		Average	11.3%	4.3%
	Standard Deviation		3.4	1.3

SOURCE: Arthur D. Little, Inc., based on Standard & Poor's Corporation, Value Line, and Company reports.

TABLE IV-11

ESTIMATED CAPITAL EXPENDITURES FOR THE DOMESTIC PRIMARY COPPER INDUSTRY

	1972	1973	1974	1975
	------ Millions	of Dollars-----		
Mining and Milling[a]	233[c]	420	465	430
Smelting Capacity	18	45	70	74
Refining Capacity[b]	6	34	56	44
Pollution Control				
Smelters	105[d]	150	180	142
Other	3	5	8	18
TOTALS[a,e]	365	654	779	708

NOTES: [a] Includes capitalized mine development expenses and interest during construction.

[b] 1973-1975 refinery expenditures dominated by Asarco's new Amarillo refinery.

[c] Reasonable agreement with 1972 Census.

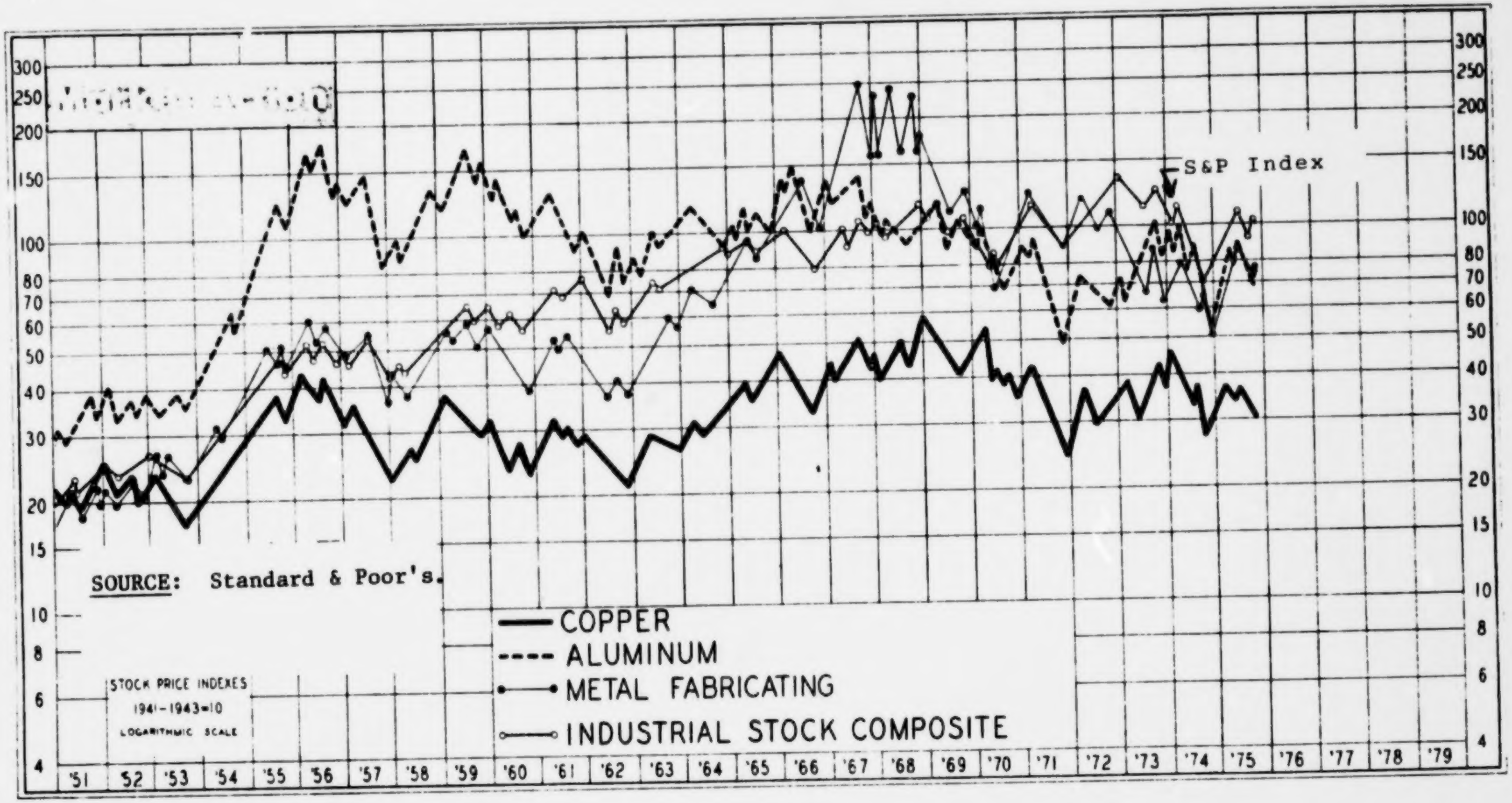
[d] Cf. MA-200(73)-2, Expenditures for Pollution Abatement, U.S. Department of Commerce Report, 1973.

[e] Cf. Census Reports for Ore Mining and for Copper Smelting and Refining (SIC 33).

SOURCE: Arthur D. Little, Inc. estimates.

FIGURE IV-1

BEHAVIOR OF COMMON STOCK PRICES



SOURCE: Standard & Poor's.

zero growth in earnings, one model of the cost of equity capital is the reciprocal of the price-to-earnings ratio.

Copper issues sold at about ten times earnings in 1965 (or 60 percent of the Industrial's P/E), and at about 6.2 times 1974 earnings (65 percent of the Industrial's P/E); for 1975 the comparison was not easy to establish because of several complicating developments with respect to the copper companies, including consolidations, acquisitions, and losses on operations for some companies.

In current dollar terms, these P/E relationships suggest a cost of new equity capital in the range of 15 to 19 percent, consistent with data and estimates of the cost of capital made by Pogue, and our own estimates as explained formally in the Technical Appendix to this report[6].

4. Long-Term Debt and Trend in Debt-to-Equity Ratios

a. Term Structure of Debt for the Primary Nonferrous Metals Companies

The debt structure of the primary copper producers was studied along with that of the primary lead and zinc companies, using data published in the annual reports of the subject companies. This includes all nine primary copper producers except the major oil companies Cities Service and Pennzoil.

The long-term obligations of each company and its consolidated subsidiaries are reviewed below in tables breaking debt down by maturity and rate of interest. Wherever rates were not specified, the amounts were placed in an interest category labeled "Other", by year of maturity. Pollution control-related debt was identified. Capitalized leases are included, as are sinking fund payments.

It should be noted that while reasonable care was taken in compiling this data and presenting it in as consistent a fashion as possible, we cannot guarantee absolute comparability from one company to the next, due to differences in the nature of their debt, differences in their accounting for certain balance sheet items, etc. To the best of our knowledge, the data herein present a meaningful basis for study and comparison.

Table IV-12--Total Debt of Primary Copper, Lead and Zinc Producers, shows the debt and the debt repayment schedule as of December 31, 1974, for each of the companies and their consolidated subsidiaries.

TABLE IV-12

TOTAL DEBT OF PRIMARY COPPER, LEAD AND ZINC PRODUCTS[a]

(millions of dollars)

Company	Repayment Schedule 1975	1976	1977	1978	1979	1980 & Beyond	Sum=Total Long-Term Debt 12/31/74	Long-Term Debt 6/30/75[g]
Asarco	18.2	6.7	4.7	8.4	9.2	237.4	266.4[d]	285.3
Anaconda	16.8	59.4	8.4	19.6	16.7	301.6	405.7[c]	476.4
Cyprus Mines	1.5	6.7	11.5	10.9	10.7	70.5	110.3[e]	115.0
Copper Range	1.4	1.4	2.7	2.7	2.7	23.2	32.7	32.7
Inspiration	5.9	5.7	5.7	6.2	5.3	23.4	46.3	43.3
Kennecott	8.8	7.2	6.4	4.2	2.4	206.2	226.4	443.6
Phelps Dodge	2.4	2.5	27.5	52.5	13.0	301.6	397.1[f]	525.4
Newmont	13.0	17.4	20.8	24.8	27.2	119.2	209.4	256.0[h]
Amax		30.4	13.8	63.7	43.3	249.7	400.9	545.2
Gulf Resources	2.3	2.2	2.1	6.8	5.8	72.2	89.1	72.4
St. Joe	8.4	5.9	4.1	2.7	1.0	22.0	35.7	35.6
Engelhard	2.9	7.1	4.7	3.4	5.5	93.2	113.9	113.6
Total Long-Term Debt		152.6	112.4	205.9	142.8	1,670.2	2,333.9[b]	2,944.5

NOTES AND SOURCES:

[a] Source: 1974 Annual Reports, SEC Form 10-K reports, and Arthur D. Little, Inc.

[b] Does not include 1975 current installment of $81.6 million.

[c] Capitalized leases account for $131.9 million of LTD.

[d] Includes notes and debentures issued in January 1975 for $150 million.

[e] Includes notes issued in January 1975 for $100 million.

[f] Includes $70 million of indebtedness to finance air quality control facilities, incurred in January, 1975.

[g] Source; Company 1975 reports and Arthur D. Little, Inc.

[h] First quarter data.

Information used to prepare this table was taken from sources believed to be reliable, but its accuracy and completeness are not guaranteed.

Table IV-13--Debt of Primary Copper, Lead and Zinc Producers by Period of Maturity and Interest Rate (Percent), shows the total debt by period within certain interest ranges. The "Other" category was used for debt which rate of interest was unidentified.

Figure IV-2--Term Structure of Debt for Primary Nonferrous Metals Companies, is a bar chart showing the amount of debt by interest rate and the maturity periods for the companies listed.

Total long-term debt at year-end 1974 exceeded $2 billion, and debt-equity ratios were approaching 30/70. The overall average for the 550 companies studied by Business Week showed a capital structure with 60 percent equity and 40 percent debt (long-term and short-term), as of the end of March 31, 1975.

b. Review of Pollution Control Debt Issues

Table IV-14--Debt Allocated for Pollution Control Purposes, Including Certain Capitalized Lease Obligations, shows the debt allocated to pollution control by the subject companies. In 1974, about 14% of the total debt was specifically earmarked for pollution control. Variability in how companies report may understate the total debt issues committed to pollution control. In any case, the total amount has grown significantly since 1974.

- Inspiration Consolidated Copper Company carried long-term debt of $33.2 million at December 31, 1974, used to finance construction of pollution control facilities. Funds were obtained for this loan from the sale by an Industrial Development Authority of tax-exempt Pollution Control Revenue Bonds. The company has guaranteed the Authority's payment of principal and interest on these bonds. Interest is at 75 percent of the prime rate charged by The Chase Manhattan Bank. As discussed in Appendix A, repayment was scheduled in 36 quarterly installments of $900,000 and a final payment of $800,000 on February 15, 1984.

- St. Joe Minerals Corporation and its consolidated subsidiaries had a liability of $18.361 million as of December 31, 1974, with respect to pollution control revenue bonds and entered into agreements with the State Environmental Improvement Authority (Missouri) and Beaver County (Pennsylvania) Industrial Development Authority to make payments to trustees under installment sales agreements sufficient (together with other available funds) to pay all amounts due on the bonds. The bonds are subject to optional redemption commencing in 1982 and mandatory redemption in 1988. The proceeds from the sale of the bonds were to provide funds for

TABLE IV-13

TOTAL DEBT OF PRIMARY COPPER, LEAD AND ZINC PRODUCERS[a] BY PERIOD OF MATURITY AND INTEREST RATE (PERCENT)

(Millions of dollars)

Matures	4 - 5-7/8	6 - 7-7/8	8 - 9-7/8	10 and Over	Other[b]	Total
1975-1979	$100.2	$ 384.8	$ 127.8	$ 82.5	$ 37.0	$ 732.3
1980-1984	117.4	320.2	260.8	19.4	23.6	741.4
1985-1989	86.4	167.5	172.5		3.5	429.9
1990-1999	49.6	227.2	155.3		4.2	436.3
2000 and Beyond		55.7	16.0			71.7
Unknown					3.9	3.9
	$353.6	$1,155.4	$ 732.4	$101.9	$ 72.2	$2,415.5[c]

NOTES AND SOURCES:

[a] Source: Arthur D. Little, Inc. estimates based on company 1974 annual reports and SEC 10-Ks.

[b] Other = Interest rate not indicated and, in some cases, final repayment date not given.

[c] Includes debt through January 1975, as given in annual reports.

Information used to prepare this table was taken from sources believed to be reliable, but its accuracy and completeness are not guaranteed.

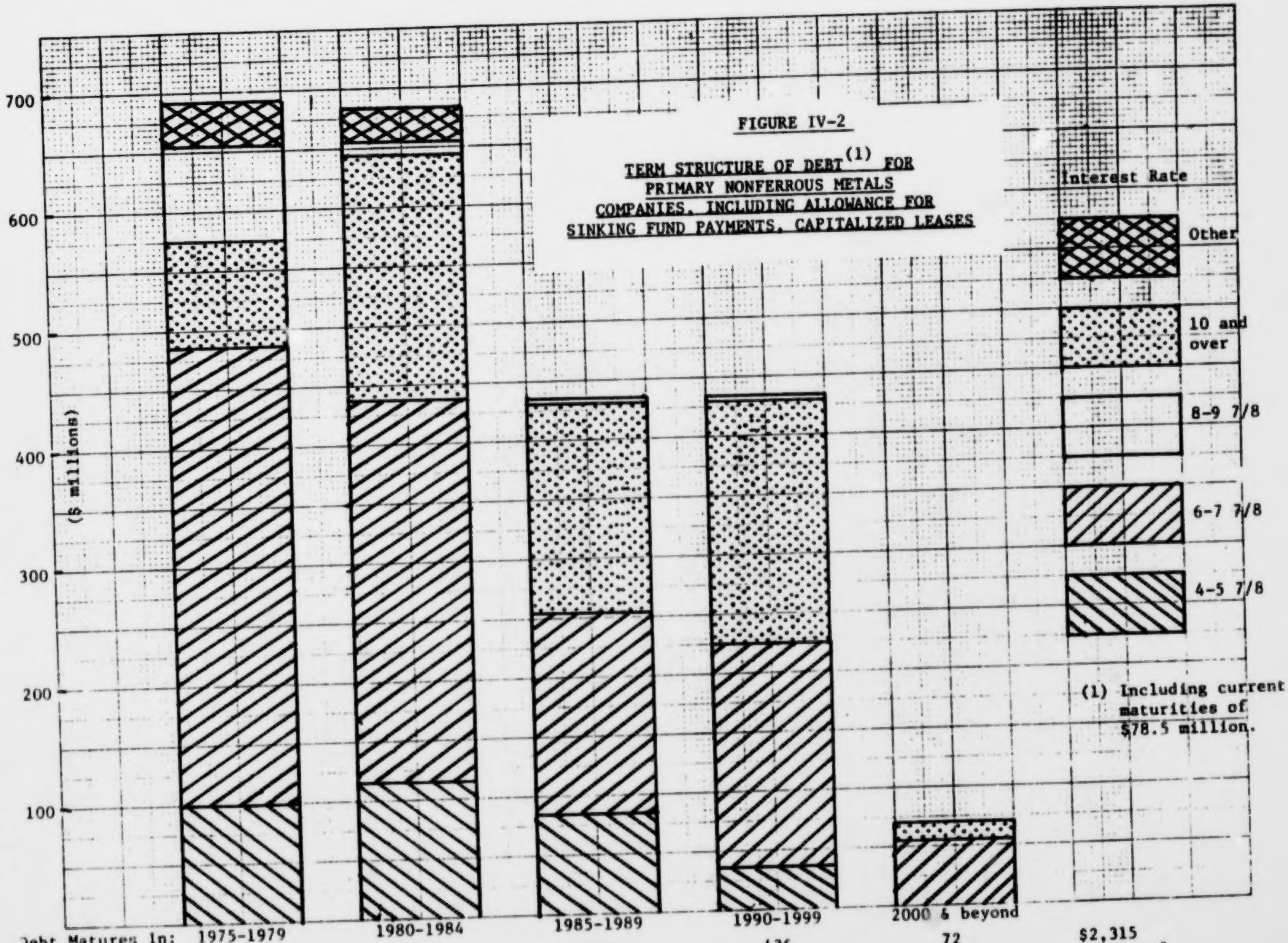


FIGURE IV-2

TERM STRUCTURE OF DEBT(1) FOR PRIMARY NONFERROUS METALS COMPANIES, INCLUDING ALLOWANCE FOR SINKING FUND PAYMENTS, CAPITALIZED LEASES

Debt Matures In:	1975-1979	1980-1984	1985-1989	1990-1999	2000 & beyond	
Total ($ millions)	$692	681	430	436	72	$2,315
PCRB ($ millions)	68	118	21	56	56	289

(1) Including current maturities of $78.5 million.

TABLE IV-14

DEBT ALLOCATED BY PRIMARY COPPER, LEAD AND ZINC PRODUCERS FOR POLLUTION CONTROL PURPOSES, INCLUDING CERTAIN LEASE OBLIGATIONS

(millions of dollars)

Period	Debt
1975 - 1979	$ 67.8
1980 - 1984	117.9
1985 - 1989	21.0
1990 - 1999	55.5
2000 and Beyond	55.7
	$317.9[a]

NOTES AND SOURCES:

[a] The pollution control obligations of the copper, lead and zinc companies was equal to about 14.0% of total debt at year-end 1974.

Information used to prepare this table was taken from sources believed to be reliable but its accuracy and completeness are not guaranteed.

the construction of pollution control facilities at St. Joe Minerals' lead and zinc smelters. The debt at December 31, 1974, represents the amount of proceeds from the sale of bonds applied to construction payments; the balance of the proceeds is held and invested by the trustees pending disbursements and, if not applied toward construction payments, is available to service the bonds or to repay them in part.

- Newmont Mining's subsidiary, Magma Copper Company, had $30 million of air pollution control bonds outstanding as of December 31, 1974, payable at 3.67 percent ± 50 percent of the difference between prime rate and 5 percent payable 1975 to 1982.

- Asarco sold $10 million of Gila County, Arizona, pollution control bonds in 1974, and indicated that it would seek additional pollution control revenue bond financing. As of December 31, 1974, there was $8.4 million of this long-term debt issue, with interest at 75 percent of prime, due in quarterly installments to August 31, 1982. The company's prospectus dated May 7, 1975, stated that it was negotiating additional revenue bond financing for qualified pollution control facilities. (By mid-1976 the amount so financed was $50 million).

- Phelps Dodge as of December 31, 1974, had $135.782 million in tax-exempt air quality control obligations due after one year. In January, 1975, the Corporation also incurred $70 million of indebtedness to finance the air quality control facilities at its new Hidalgo smelter. The indebtedness bears interest at a rate of 7.25 percent per annum. Principal payments are due in 1979 (15 percent), 1980 (15 percent), 1981 (30 percent), and 1982 (40 percent).

- Kennecott--see Appendix A.

- Anaconda financed the first stage of the installation of an acid plant and related equipment at the copper smelter at Anaconda, Montana, which was completed in 1973 at a cost of approximately $21.1 million, by a leasing arrangement under which the County of Deer Lodge, Montana, issued $17 million in tax-exempt bonds and a third party invested the balance. The second stage, which involves installation of an electric furnace and related control equipment, is nearing completion[7]. Use of an electric furnace is expected to substantially eliminate air pollution. Construction funds for this stage are beind made available, up to an expected total of approximately $31.5 million, from working capital and bank loans. Anaconda also installed a major pollution control system in the course of construction of its aluminum smelter at Sebree, Kentucky. Funds totaling $10.6 million were made available for this project through a lease financing with several large institutional investors.

c. Trends in Debt Ratio for Leading Nonferrous Metals Companies

The debt ratios computed for 12 primary copper, lead and zinc companies, expressed as percent, were computed as follows:

$$D' \equiv \text{Debt ratio (percent)} = \left(\frac{D}{D+E}\right) \times 100, \text{ where}$$

D = total long-term debt, excluding current installments

E = total shareholders' equity[8]

Long-term debt for most of the companies whose financial results were reviewed peaked in 1971 to 1973. By the end of 1974 the long-term debt of nine of the 12 companies hit a three-year low, but by mid-1975, several of these companies had large increases in their long-term debt (Amax, Anaconda, Asarco, Cyprus Mines, Kennecott, Newmont, and Phelps Dodge). Six of these companies each had long-term debt of $250 million or more outstanding on June 30, 1975. The seventh, Cyprus Mines, which in January, 1975, increased its debt by $100 million, had $115 million.

The long-term debt of the 12 companies increased from $1,224 million at the end of 1970 to $2,014 million by December 31, 1974, and then sharply rose to $2,944.5 million by June 30, 1975. In January, 1975, three large debt offerings were made. Asarco issued $150 million in notes and debentures, Phelps Dodge added $70 million to its long-term debt, and Cyprus Mines issued $100 million of notes; of these new additions, the $70 million was for Pollution Control Revenue Bonds.

Shareholders' equity rose from $5,665 million to $7,347 million from December 31, 1970 through December 31, 1974 (30 percent), and by June 30, 1975 was $7,458.9 million, up 1.6 percent from the December amount.

The debt ratios of the companies studied appear in Table IV-15. The percentage stayed fairly constant for some companies between 1970-1974. The larger, integrated companies showed more stable ratios than the others. As we have shown in the footnotes to Table IV-15, Asarco's, Cyprus Mines', and Phelps Dodge's ratios increased sharply in January, 1975.

TABLE IV-15

LONG-TERM DEBT OF TWELVE COPPER, LEAD, ZINC PRODUCERS[a]

(millions of dollars)

	1970	1971	1972	1973	1974
Amax, Inc.	261.5	392.0	457.4	440.7	400.9
Asarco	23.7	38.1	51.0	91.7	266.4[b]
Anaconda	366.5	391.5	388.9	379.3	405.9
Copper Range	24.3	36.3	35.0	33.6	32.7
Cyprus Mines	40.4	34.9	22.4	17.1	110.3[c]
Engelhard	80.4	77.2	117.7	115.5	113.9
Gulf Resources	42.0	48.6	53.1	73.6	89.1
Inspiration Consolidated	1.26	1.14	19.1	49.8	46.3
Kennecott	177.9	314.6	269.0	220.8	226.4
Newmont Mining	108.4	201.6	224.0	218.1	209.4
Phelps Dodge	86.1	166.0	181.3	281.9	397.1[d]
St. Joe Minerals	11.7	10.7	34.7	50.3	35.7
Total	1,224.2	1,712.6	1,853.6	1,972.4	2,334.1[b,c,d] 2,014.1 (year-end)

NOTES AND SOURCES:

[a] Source: Annual Reports, SEC 10-K's, S&P report, and Arthur D. Little, Inc. Includes capitalized leases, convertible subordinated debentures, and sinking fund debentures. Does not include current installment.

[b] Includes $150 million notes and sinking fund debentures issued in early 1975.

[c] Includes $100 million of notes issued in January 1975.

[d] Includes $70 million of indebtedness to finance air quality control facilities incurred in January 1975.

Information used to prepare this table was taken from sources believed to be reliable, but its accuracy and completeness are not guaranteed.

5. Indicators of the Ability to Attract Additional Capital

Table IV-16 presents long-term debt, long-term debt as percent of invested capital, and shareholders' equity for leading nonferrous metals producing companies, including aluminum producers, as of June 30, 1975. Also shown are some indicators of ability to attract additional capital.

Only four of the 16 companies had a capital structure that was leveraged about equal to, or greater than, the overall average for the 550 companies reported in the Business Week study mentioned earlier.

Several nonferrous metals companies showed a decline in their pre-tax interest coverage ratios from the average interest coverage ratio pre-tax, 1965-1974. By March 31, 1975, Kennecott, Asarco, Anaconda, and Phelps Dodge each declined by about 80 percent of their previous coverage as expressed by the ten-year average. Business Week reported that interest-coverage ratio for the overall average of 550 companies had slipped to 9.9, and that in the ten years past it was 18.5. Only five of the twelve companies in the Table IV-16 had ratios of ten or more.

During the first part of 1975, much of the United States economy, and the nonferrous metals business, was still in the grips of the severe recession which began in late 1973. Very few of the primary nonferrous metals producers' share prices were selling above the book value of the equity. This is shown in Table IV-16 and specifically for the copper companies in Summary Table IV-3. Even if it had been feasible during the generally poor business climate of 1975, equity financing would have been painful when stocks were selling below book value. On the other hand, given substantial discounts on productive long lived assets with much greater replacement cost than their book value, the shares of such companies have been sought in several cases by acquisition/diversification-minded firms outside the industry. The entrance of oil companies, mentioned earlier, is an example. As far as financing new or incremental plant and equipment related to copper production, then, these "outside" firms become new sources of capital at a cost which is reflective of their own opportunity costs or hurdle rates.

E. DESCRIPTION OF THE BUSINESS OF THE MAJOR COPPER PRODUCERS

Appendix A was prepared in conjunction with this section to highlight the nature of each company's business and describe some of the pertinent features of its operations. Additional information, in the form of statistical data for the last five (or ten) years, is also presented. The eleven companies described herein account for typically 95 percent or more of United States mine output and refinery production.

TABLE IV-16

NONFERROUS METALS COMPANIES COMPARISONS

Long-Term Debt, Shareholders' Equity, and Indicators of Ability to Attract Additional Capital

	Long-Term Debt 6/30/75	Long-Term Debt as % of Invstd. Capital 6/30/75	Share-holders' Equity 6/30/75	Stock Price as % of Book Value, Mid-1975	Av. Int. Covge. Ratio Pre-tax 3/31/75	Av. Int. Covge. Ratio Pre-tax 1965-74	S&P Bond Rating
Aluminum Co. of America	1,179.9	42.7	1,585.2	1.0	5.4	5.4	A
Amax, Inc.	545.2	36.1	965.5	1.3	9.6	9.1	A
Anaconda	476.4	27.8	1,234.4	0.3	4.8	20.5	A
Asarco	285.3	24.8	863.9	0.4	11.3	48.9	A
Copper Range	32.7	27.7	117.9	-	10.7[c]	-	-
Cyprus Mines	115.0	26.2	324.0	0.8	26.0	28.5	A
Engelhard	113.6	20.0	454.3	1.5	7.6	5.4	BBB[e]
Gulf Resources	72.4	39.9	109.0	1.8	2.7	-	-
Inspiration Consolidated	43.4	26.3	90.1	0.7	1.1[c]	-	-
Kaiser Aluminum	684.7	46.1	799.3	0.8	4.4	3.2	-
Kennecott Copper	443.5	23.6	1,436.4	0.7	10.4	75.4	A
Martin Marietta	279.4	32.2	589.3	0.7	6.8	8.3	BBB
Newmont Mining	256.0	28.7	637.4	0.8	8.0	-	-
Phelps Dodge	525.4[a]	37.0	893.9	0.8	5.3	18.7	A+
Reynolds Metals	816.4[b]	50.2	809.3[b]	0.5	3.3	2.9	B[e]
St. Joe Minerals	35.6	9.7	332.1	1.9	33.9[d]	40.9	-
12 Copper, Lead, Zinc Companies	2,944.5		7,458.9				
4 Aluminum Company's	2,960.4		3,783.1				
Total	$5,904.9 MM		$11,242.0 MM				

NOTES:

[a] Includes $125M of offered notes in 1975.

[b] Reflects restructure of the company's investment in a primary aluminum smelter and rolling mill in Hamburg.

[c] December 1974 data.

[d] Based on company's fiscal year end.

[e] Subordinate debt rating.

SOURCE: Business Week Survey September 22, 1975; and Arthur D. Little, Inc.

In general, with respect to primary copper production, Phelps Dodge is thought to be the lowest cost producer; Copper Range and Anaconda the highest cost producers.

These three companies plus Inspiration Consolidated have a heavy dependence on domestic production of copper in their operations, and in terms of sales and earnings. On the other hand, Amax, Asarco, Cities Service, Cyprus Mines, Newmont and Pennzoil are more diversified by lines of business and/or derive significant earnings from investment holdings in other companies, including foreign mining ventures.

Except for Cities Service and Pennzoil, the major influences on sales and earnings, from the companies' viewpoints, are nonferrous metals facilities operating rates and metal prices. These fluctuate much more than annual consumption or demand. Metal prices reflect the nature of the commodity markets, and the profitability of all producers is most sensitive to changes in refined metal prices.

CHAPTER IV

NOTES

1. Internal Revenue Code regulations governing the calculation of the depletion allowance from mining operations are involved here: There is a provision for cost/profit allocation when there is no established field or market price for captive concentrates shipped from an area to a company's smelter. In practice, there is considerable flow of concentrates (e.g., between one company's mines and another company's smelter), and hence the field or market price may be easily established.

2. Cerro has a gross fabrication capacity for tubing, wire and cable, and brass mills products of 350,000 tons/year (nearly 15 percent of the total). General Cable was spun off from Asarco in 1967, in connection with a consent decree arising from an antitrust action. Other large independent capacity is represented by that owned and utilized captively by General Electric Company and the Western Electric subsidiary of American Telephone and Telegraph Company.

3. See also, for example, U.S. vs. Kennecott Copper, in which Kennecott was required to divest Okonite Company, an independent wire and cable producer acquired in 1958; and "Dual Distribution", Hearings before the Senate Subcommittee on Antitrust and Monopoly, Committee on the Judiciary, September 15-17, 1965.

4. In 1975-1976, Continental Oil Company was considering a large new copper mining development, with annual production on the order of 100,000 tons per year. Conoco would have been the sixth major oil company producer, although its entry would be as a new producing firm, increasing the number of competitors. Reportedly, weak copper prices have tabled this project.

5. Exxon also recently announced its direct interest in a large ore body in Wisconsin, containing significant amounts of copper and other mineral values. Exxon is studying the opportunity to exploit this property.

6. See Arthur D. Little, Inc. (ADL), Econometric Simulation and Impact Analysis Model of the U.S. Copper Industry, Technical Appendix to Economic Impact of Environmental Regulations on the U.S. Copper Industry (1976), Supporting Paper 3: "Analysis of the Cost of Capital for the Primary Producers".

7. A major additional pollution control revenue bond financing was completed by Anaconda more recently.

8. Note that if $D' \equiv \frac{D}{D+E}$, then Debt : Equity = $\frac{D}{E} = \frac{D'}{(1-D')}$

V. RELATIONSHIP TO THE WORLD INDUSTRY

A. INTRODUCTION

Although the United States is virtually self-sufficient in copper, the United States copper industry does not exist in isolation from the rest of the world. This chapter presents an overview of the United States copper industry in world perspective, by reviewing comparative United States and world pattern of copper consumption, production, capacity and ore reserves, examining the structure of the United States and world trade flows, and describing basic changes in the structure of the world copper industry during the postwar period.

The United States, despite its declining share of total world consumption and production, still accounts for 24 percent of total world consumption and production, and over 18 percent of total world mine output (22 percent of world refined copper output). The United States also contains one-fifth of the world's copper reserves and other resources, the distribution of which approximates the regional pattern of present production, with two exceptions: South America has a larger proportion of world copper reserves than of production, while the opposite is true for Europe (defined more broadly to include U.S.S.R. and Poland). Developing countries account for nearly 60 percent of world copper reserves--more than 1.5 times their share of world output.

The United States, which has been nearly self-sufficient in copper except in certain years coinciding with military developments or unusual "demand-crunch" periods, is both a leading importer and exporter of copper. Even after accounting for increased United States import-dependence in the future, the United States is not likely to be as vulnerable to international supply interruptions (via cartelization, etc.) as would be Western Europe and Japan which are highly import-dependent.

During the postwar period, significant changes have occurred in the structure of the world copper industry. These changes are relevant in examining the long-term economic implications of United States environmental regulations affecting the copper industry. These changes have taken two basic directions. First, the copper industry has become not only more diversified geographically with the emergence of new producing countries but also relatively less concentrated, as new firms have entered the industry to expand the industry's production significantly during this period. Second, the nationalization of copper mining and processing operations in major copper exporting developing countries has brought about a significant shift in ownership patterns in the world copper industry in recent years. We believe this has at least three major implications.

First, it could, over the long-run, lead to increased vertical integration of copper production in the copper exporting developing countries.

Second, it could strengthen the position of these countries in moving towards the establishment of an international commodity agreement on copper, based on a buffer stock arrangement, which would mean higher but less volatile (i.e., more stable) world copper prices. A necessary but not sufficient condition favoring such a development would be healthy macroeconomic recovery and growth in the industrialized countries, including the United States, combined perhaps with higher production costs and a possible smelter capacity bottleneck in the United States over particularly the period 1978-1983 brought about both by environmental regulations (past and in the future) and by the adverse macroeconomic conditions experienced in recent years which have discouraged domestic capacity expansion.

Third, if worldwide macroeconomic recovery and growth--especially in the OECD-European countries--continues at a relatively slow pace during the next few years, such a shift in ownership patterns could mean the continuation into the future of the currently prevailing two-price system in the world copper market, the chief characteristic of which is that the LME prices are below the United States primary producers' prices. As noted in Chapter VIII-Prices, this could mean relatively low worldwide copper prices brought about by continued high levels of production in the copper exporting developing countries to meet their growing foreign exchange requirements. The result would be much higher United States imports and a financially precarious domestic copper industry during at least the next few years, until self-correcting economic forces cause a reversal.

B. COMPARATIVE UNITED STATES AND WORLD TRENDS IN COPPER CONSUMPTION, PRODUCTION, CAPACITY AND ORE RESERVES

The United States, despite its declining share of total world consumption and production, still accounts for about 24 percent of total world consumption and production, and over 18 percent of total world mine output (22 percent of refined copper output). The United States also contains one-fifth of the world's copper reserves. Copper production worldwide is highly concentrated in a few countries. While the degree of concentration in smelting is quite similar to that in mining, concentration by country in refining displays a different pattern where several leading industrial countries with very little or no mine production, or even with very little smelter production, are large copper refiners.

1. Comparative United States and World Consumption Trends

World consumption of refined copper was about 8.3 million metric tons in 1974[1]. Of this, United States consumption accounted for nearly 2.0 million metric tons or 23.5 percent. The United States share of world consumption of refined copper dropped from 28.8 percent in 1963 to 23.5 percent in 1974, reflecting a relatively higher growth in demand for copper in the rest of the world (Table V-1). Accordingly, while refined copper consumption in the United States has increased by only 1.90 percent per year during the 1963-1974 period (1.47 percent/year over 1964-1974 and 3.39 percent/year over 1963-1974), world consumption has recorded a substantially higher rate of growth at 3.81 percent per year over the sample period (3.34 percent/year over 1964-1974 and 4.77 percent/year over 1963-1973).

As shown in Table V-2, fifteen countries accounted for 88.1 percent of total world refined copper consumption in 1974, while these countries produced only 53.6 percent of total world mine output of copper. When the United States and the U.S.S.R. (two virtually self-suffient countries) as well as Canada (a major exporter), are excluded, the picture becomes substantially different: while the remaining twelve largest consumers together account for 47.3 percent of total world consumption of refined copper, their combined mine output amounts to only 9.6 percent of the world total.

Although not shown in the accompanying tables, annual copper consumption reported by individual countries tends to be quite cyclical, particularly in the United Kingdom, the United States, and West Germany. Year-to-year changes of plus or minus ten percent are common and changes exceeding 20 percent have not been unusual. Cyclical downturns in some countries tend to be offset by upswings in others. Even though this may serve to smooth the trend in total consumption, copper production generally tends to be more stable over time than overall copper consumption.

2. United States and World Production Trends

Analysis of world copper production trends in somewhat complicated by the role of secondary copper and the difficulty of separating copper of primary origin from that originating from scrap, especially after the latter has been re-refined.

TABLE V-1

UNITED STATES AND WORLD COMPARATIVE TRENDS IN REFINED COPPER CONSUMPTION, 1963-1974

(thousand metric tons)

Years	U.S.	World	U.S. as percent of world
1963	1590.0	5519.3	28.8
1964	1690.0	5995.4	28.2
1965	1845.6	6193.2	29.8
1966	2157.8	6444.8	33.5
1967	1797.5	6194.8	29.0
1968	1701.4	6523.3	26.1
1969	1944.3	7148.0	27.2
1970	1854.3	7283.4	25.5
1971	1830.5	7309.9	25.0
1972	2028.6	7944.5	25.5
1973	2218.6	8791.6	25.2
1974	1956.4	8325.4	23.5
Average Annual Compound Growth Rate (Percent)			
1963-1973	3.39	4.77	-
1964-1974	1.47	3.34	-

SOURCE: Metallgesellschaft Aktiengesellschaft, Metal Statistics 1963-1973 and 1964-1974, pp. 32-33.

TABLE V-2

REFINED COPPER CONSUMPTION AND MINE PRODUCTION OF COPPER, BY FIFTEEN LARGEST CONSUMING COUNTRIES, 1974

Country	Consumption of Refined Copper[a]		Mine Production of Copper[a]	
	Amount (thousand metric tons)	Percent (%)	Amount (Copper content, thousand metric tons)	Percent (%)
United States	1,956.4	23.5	1,445.7	18.3
Canada	270.1	3.2	826.2	10.5
Japan	831.0	10.0	82.1	1.0
Germany, FR	731.0	8.8	1.7	-
Belgium-Luxembourg	178.2	2.1	-	-
France	414.2	5.0	0.4	-
Italy	308.0	3.7	0.8	-
United Kingdom	496.9	6.0	-	-
Spain	143.9	1.8	44.5	0.6
Brazil	162.0	1.9	6.0	0.1
Australia	121.6	1.5	255.6	3.2
U.S.S.R.	1,170.0	14.1	1,200.0	15.2
Germany, DR	105.0	1.3	18.0	0.2
Poland	150.0	1.8	198.0	2.5
China, PR and North Korea	300.0	3.6	150.0	1.9
Subtotal	7,338.3	88.1	4,229.0	53.6
World Total	8,325.4	100.0	7,885.6	100.0

NOTES: [a] Components may not sum up to the totals given due to rounding.

SOURCE: Metallgesellschaft Aktiengesellschaft, Metal Statistics, 1964-1974, 62nd. Edition, (Frankfurt am Main, 1975), various pages.

World production of refined copper in 1974 was approximately 8.9 metric tons (smelter production about 7.7 million metric tons and mine output about 7.9 million metric tons), as shown in Table V-3. The United States accounted for 18.3 percent of mine output, 18.4 percent of smelter output and 21.9 percent of refined production.[2] The share of the United States in world refined copper production dropped from 31.7 percent in 1964 to 21.9 percent in 1974 (Table V-4). During the same period, United States smelter output share dropped from 25.4 percent to 18.4 percent, while United States mine output share dropped from 23.8 percent to 18.3 percent. United States mine output has grown at 2.48 percent per year over the 1964-1974 period (compared to world average of 5.09 percent per year) and 3.54 percent per year over the 1963-1973 period (compared to world average of 5.08 percent per year).

3. Distribution of Production and Capacity

At the mining level, copper output and productive capacity are highly concentrated in a relatively few countries, with the United States still as the largest single producer (Tables V-5 and V-6). The United States has been the leading copper-producing country since 1883, except for 1934 when economic conditions adversely affected domestic production. In 1974 the next five principal copper-producing countries, in ranked order, were Chile, Canada, the U.S.S.R., Zambia and Zaire. These countries, together with the United States, accounted for 71.2 percent of total world mine output (1974). This reflects only a slight downward shift in geographical concentration over the previous decade, with the same six countries having accounted for 78.3 percent of total world mine output of copper in 1964. Chile, Zambia, Peru and Zaire, which in 1968 formed the Conseil Intergouvernemental des Pays Exportateurs de Cuivre (CIPEC), also known as the Intergovernmental Council of Copper Exporting Countries[3], together account for about 30 percent of total world and mine production in copper (Table V-6).

Among the more striking conclusions that can be drawn here are the following:

- United States mine productive capacity (i.e., mine/mill capacity) only slightly exceeds the estimated combined capacity of the Sino-Soviet Block countries as a whole,
- about 80 percent of world mine productive capacity is located outside the Sino-Soviet Block countries,
- Chile, Peru, Zambia and Zaire, original founders of CIPEC, together account for about 30 percent of world capacity and 36 percent of total Free World capacity.

TABLE V-3

WORLD PRODUCTION OF COPPER, 1974[a]

(thousand metric tons)

Country Groups	Mine production (copper content)		Smelter Production		Production of refined copper	
	Amount	Percent (%)	Amount	Percent (%)	Amount	Percent (%)
Total World	7,885.6	100.0	7,733.6	100.0	8,851.5	100.0
United States	1,445.7	18.3	1,424.2	18.4	1,938.3	21.9
Other America	2,042.6	25.9	1,518.6	19.6	1,241.7	14.0
Europe	322.1	4.1	538.1	7.0	1,447.4	16.4
Asia	447.7	5.7	970.4	12.5	1,608.2	12.1
Africa	1,519.1	19.3	1,411.7	18.3	1,051.8	11.9
Australia and Oceania	439.7	5.6	195.6	2.5	189.6	2.1
Communist Block Countries	1,668.7	21.2	1,675.0	21.7	1,914.5	21.6

NOTES: [a] Components may not sum up to the totals given due to rounding.

SOURCE: Metallgesellschaft Aktiengesellschaft, Metal Statistics 1964-1974, 62nd. Edition (Frankfurt am Main, 1975), pp. 26-31.

TABLE V-4

UNITED STATES AND WORLD COMPARATIVE TRENDS IN COPPER PRODUCTION: 1963-1974

(thousand of metric tons)

Years	Mine Production of Copper (copper content)			Smelter Production of Copper			Production of Refined Copper		
	U.S.	World	U.S. as percent of world	U.S.	World	U.S. as percent of world	U.S.	World	U.S. as percent of world
1963	1100.6	4624.3	23.8	1176.3	4634.8	25.4	1709.5	5399.7	31.7
1964	1131.1	4798.6	23.6	1214.2	4851.4	25.0	1805.7	5739.0	31.5
1965	1226.3	4962.7	24.7	1300.9	5024.4	25.9	1942.1	6058.5	32.1
1966	1296.5	5215.9	24.9	1330.3	5167.0	25.7	1980.7	6322.2	31.3
1967	865.5	5057.6	17.1	782.3	4891.0	16.0	1384.9	6000.5	23.1
1968	1092.8	5456.5	20.0	1148.9	5507.8	20.9	1668.3	6658.6	25.1
1969	1401.2	5951.2	23.5	1438.3	5972.9	24.1	2009.3	7199.8	27.9
1970	1560.0	6387.3	24.4	1489.0	6309.5	23.6	2034.5	7577.8	26.8
1971	1380.9	6473.9	21.3	1360.8	6380.0	21.3	1780.3	7377.8	24.1
1972	1510.3	7071.5	21.4	1533.5	7003.2	21.9	2048.9	8068.0	25.4
1973	1558.5	7591.4	20.5	1582.1	7445.5	21.2	2098.0	8497.3	24.7
1974	1445.7	7885.6	18.3	1424.2	7933.6	18.4	1938.3	8851.5	21.9
Average Annual Compound Growth Rate (Percent)									
1963-1973	3.54	5.08	-	3.01	4.85		2.07	4.64	-
1964-1974	2.48	5.09	-	1.61	4.77	-	0.71	4.43	

NOTES: [a] One metric ton (1,000 kilograms) equals 1.102311 short tons (907.185 kilograms = 2000 pounds avoirdupois, where one pound avoirdupois equals 0.453592 kilogram or 453.5924 grams).

SOURCE: Metallgesellschaft Aktiengesellschaft, Metal Statistics 1963-1973, 61st Edition (Frankfurt am Main, 1974), pp. 26-31; and Metal Statistics 1964-1974, 62nd Edition (Frankfurt am Main, 1975), pp. 26-31.

TABLE V-5

WORLD COPPER MINE PRODUCTIVE CAPACITY, BY AREA AND COUNTRY, 1974 AND 1975

Area/Country	Estimated Capacity (thousands of short tons)		Percent Breakdown (%)	
	Dec. 31, 1974	Dec. 31, 1975	Dec. 31, 1974	Dec. 31, 1975
North America				
United States	1,920	2,050	20.6	21.6
Canada	1,020	980	11.0	10.0
Mexico	95	100	1.0	1.1
Other	10	10	0.1	0.1
Total	3,045	3,140	32.7	33.0
South America				
Chile	1,000	1,000	10.7	10.5
Peru	245	245	2.6	2.6
Other	15	15	0.2	0.2
Total	1,260	1,260	13.5	13.2
Africa				
Zambia	850	850	9.1	8.9
Zaire	625	625	6.7	6.6
South Africa	200	200	2.1	2.1
South West Africa	35	35	0.4	0.2
Other	80	120	0.9	1.3
Total	1,790	1,830	19.2	19.2
Asia				
Philippines	265	280	2.8	2.9
Japan	85	75	0.9	0.8
Indonesia	80	80	0.9	0.8
Iran	5	5	0.1	0.1
Other	100	110	1.1	1.2
Total	535	550	5.7	5.8
Oceania				
Australia	285	275	3.1	2.9
Papua New Guinea	200	200	2.1	2.1
Total	485	475	5.2	5.0
Europe	365	375	3.9	3.9
TOTAL FREE WORLD CAPACITY	7,480	7,630	80.3	80.2
SINO-SOVIET BLOCK COUNTRIES	1,836[a]	1,880[a]	19.7	19.8
TOTAL	9,316	9,510	100.0	100.0

NOTES: [a] Actual mine production, from World Bureau of Metal Statistics (1974) and Commodities Research Unit Ltd. (1975), as reported in Enginnering and Mining Journal (March, 1976), p. 89.

[b] Components may not sum up to the totals given due to rounding.

SOURCE: Phelps Dodge Corporation; Arthur D. Little, Inc.

TABLE V-6

WORLD MINE PRODUCTION OF COPPER: FIFTEEN LARGEST PRODUCING COUNTRIES, 1964 and 1974

(copper content)

Country	Amount (thousand metric tons) 1964	Amount (thousand metric tons) 1974	Percent Composition[b] (%) 1964	Percent Composition[b] (%) 1974
United States	1,131.1	1,445.7	23.6	18.3
Canada	441.7	826.2	9.2	10.5
Chile	621.7	902.1	13.0	11.4
Peru	176.4	213.2	3.7	2.7
Zaire	276.6	544.1	5.8	6.9
Zambia	632.3	698.0	13.2	8.9
Republic of South Africa	61.3	179.1	1.3	2.3
Japan	106.2	82.1	2.2	1.0
Philippines	60.5	209.7	1.3	2.7
Australia	106.3	255.6	2.2	3.2
Papua-New Guinea	-	184.1	-	2.3
Yugoslavia	63.2	155.2	1.3	2.0
USSR[a]	650.0	1,200.0	13.5	15.2
Poland	13.4	198.0	0.3	2.5
China, PR and North Korea[a]	83.0	150.0	1.7	1.9
Subtotal	4,423.7	7,243.1	92.2	91.9
World Total	4,798.6	7,885.6	100.0	100.0

NOTES: [a] Estimates.

[b] Components may not sum up to the totals given due to rounding.

SOURCE: Metallgesellschaft Aktiengesellschaft, Metal Statistics 1964-1974, 62nd. Edition (Frankfurt am Main, 1975), pp. 26-27.

- World capacity has remained practically constant during 1974-1975, reflecting adverse market conditions.

Table V-7 gives a consolidated set of estimates of mine, smelter, and refinery capacities compared with production for principal producing countries. Mine production of copper for the United States and the world in 1973 was at approximately 86 percent and 90 percent of the respective estimated capacities. Values for operation of smelter capacity were 87 percent for the United States and 89 percent for the world. Capacity and production data for refineries are not strictly comparable[4].

Most major copper mining countries are also major smelters and their shares of smelter output (capacity) are broadly comparable to their shares of mine output (capacity). However, Canada and to a much lesser extent, Peru, and Australia have lower share of world smelter production, compared to their shares of world mine production, while the reverse is true for Japan and West Germany in particular (Tables V-7 and V-8). Both of these countries significantly increased their percentage share of world smelter capacity and production between 1964 and 1974. The Philippines exports all of its production in the form of concentrates. However, the degree of concentration in smelting by country is very similar to that in mining, and, as was true for the latter, concentration in copper changed very little over the 1967-1974 period, with the exception of a significant increase in smelter production in Japan.

Concentration by country in copper refining, by contrast, displays a different pattern, as shown in Tables V-7 and V-9. For example, several leading industrial countries with little or no mine production, and in many cases very little smelter production, are large copper refiners based on imported smelted copper and scrap. The leading examples are West Germany, Belgium-Luxembourg, and the United Kingdom, none of which has either mine production or large smelter production. The United States is the leading producer at all three stages. Japan, which accounts for only 1.0 percent of world mine output, not only accounts for 11.6 percent of world smelter output but also a similarly significant 11.8 percent of world refined copper output. Unlike Western European countries, Japan both smelts and refines most of its copper imports.

4. The World's Copper Resources and Distribution of Ore Reserves

Whether the world's finite copper resources will soon be exhausted is a question increasingly being raised as part of a general public debate on whether the world is "running out" of both energy and non-energy natural resources. In the case of copper, the question has more recently taken a more serious tone in the light of the finding, reported in the recent Leontief-United Nations study on the future of the world economy, that the world demand for copper is expected to

TABLE V-7

WORLD COPPER CAPACITY AND PRODUCTION, 1973

(thousand short tons)

	Mine		Smelter		Refinery[a]	
	Capacity	Production	Capacity	Production	Capacity	Production
North America						
Canada	1,000	899	640	546	610	548
United States	2,000	1,718	2,000[b]	1,744[c]	2,910	1,868
Other	100	97	100	81	80	58
Total	3,100	2,714	2,740	2,371	3,600	2,474
South America						
Chile	900	819	900	650	660	457
Peru	270	241	220	148	50	43
Other	30	18	10	5	40	32
Total	1,200	1,078	1,130	803	750	532
Europe						
U.S.S.R.	800	772	830	772	800	733
Other	640	611	1,070	991	1,800	1,748
Total	1.440	1,383	1,900	1,763	2,600	2,481
Africa						
Zaire	550	538	530	508	270	246
Zambia	870	779	840	759	770	704
Other	360	318	290	262	140	134
Total	1,780	1,635	1,660	1,529	1,180	1,084
Asia: Total	680	604	1,300	1,287	1,340	1,244
Oceania: Total	490	443	220	179	200	159
World Total	8,690	7,857	8,950	7,932	9,670	7,974

NOTES:

[a] Capacity for many plants includes capacity for processing scrap, tabulated production, to the extent possible, is for primary materials only.

[b] Includes equivalent capacity of direct-electrowinning plants bypassing smelting operations.

[c] Primary materials only.

SOURCE: U.S. Bureau of Mines, Copper, A Chapter from Mineral Facts and Problems, 1975 Edition, Preprint from Bulletin 667 (1976), p. 4.

TABLE V-8

WORLD SMELTER PRODUCTION OF COPPER: FIFTEEN LARGEST PRODUCING COUNTRIES, 1964 AND 1974

	Amount (thousand metric tons)		Percent Composition[c] %	
Country	1964	1974	1964	1974
United States	1,214.2	1,424.2	25.0	18.4
Canada	365.9	537.0	7.0	6.9
Chile	586.7	724.3	12.1	9.4
Peru	152.1	179.8	3.1	2.3
Zaire	276.6	469.9	5.7	6.1
Zambia	638.8	709.3	13.2	9.2
Republic of South Africa	56.3	147.8	1.2	1.9
Japan	280.9	900.0	5.8	11.6
Australia	81.9	195.6	1.7	2.5
Germany, FR	68.3	174.0	1.4	2.3
Spain	21.4	79.0	0.4	1.0
Yugoslavia[b]	49.4	142.2	1.0	1.8
USSR[a]	650.0	1,200.0	13.4	15.5
Poland	23.8	190.0	0.5	2.5
China, PR and North Korea[a]	83.0	150.0	1.7	1.9
Subtotal	4,549.3	7,223.1	93.8	93.4
World Total	4,851.4	7,733.6	100.0	100.0

NOTES: [a] Estimates.

[b] Primary copper only.

[c] Components may not sum up to the totals given due to rounding.

SOURCE: Metallgesellschaft Akiengesellschaft, Metal Statistics 1964-1974, 62nd. Edition (Frankfurt am Main, 1975), pp. 28-29.

TABLE V-9

WORLD PRODUCTION OF REFINED COPPER: FIFTEEN LARGEST PRODUCING COUNTRIES, 1964 AND 1974

Country	Amount (thousand metric tons) 1964	Amount (thousand metric tons) 1974	Percent Composition[b] (%) 1964	Percent Composition[b] (%) 1974
United States	1,805.7	1,938.3	31.5	21.9
Canada	370.1	559.1	6.4	6.3
Chile	277.9	538.1	4.8	6.1
Zaire	140.2	254.5	2.4	2.9
Zambia	497.1	678.8	8.7	7.6
Japan	341.7	996.0	6.0	11.3
Australia	101.7	189.6	1.8	2.1
Germany, FR	324.7	423.6	5.7	4.8
Spain	46.7	123.5	0.8	1.4
Belgium-Luxembourg	275.0	378.7	4.8	4.3
United Kingdom	224.9	160.1	3.9	1.8
Yugoslavia	51.9	150.6	0.9	1.7
USSR[a]	750.0	1,350.0	13.1	15.3
Poland	36.6	194.5	0.6	2.2
China, RP and North Korea	110.1	200.0	1.9	2.3
Subtotal	5,354.2	8,133.4	93.3	91.9
World Total	5,739.0	8,851.5	100.0	100.0

NOTES: [a] Estimates.

[b] Components may not sum up to the totals given due to rounding.

SOURCE: Metallgesellschaft Aktiengesellschaft, Metal Statistics 1964-1974, 62nd. Edition (Frankfurt am Main, 1975), pp. 30-31.

increase by 4.8 times between 1970 and 2000[5]. This same study, while it points to the uncertainties of estimating both future stocks of mineral resources and of future demands for minerals, asserts that known world resources of metallic minerals and fossil fuels are generally sufficient to supply world requirements through the remaining decades of this century and probably into the early part of the next century[6].

A number of distinctions are necessary in discussing reserves and resources of a given metallic mineral. Reserves are discovered or undiscovered. Discovered resources, in turn, consist of reserves, subeconomic resources, and resources that are not currently usable or recoverable (i.e., mineral occurrences).

Copper resources, which comprise all the deposits from which a useable mineral commodity can be extracted at present or will be in the future, are present on all continents and on the ocean floor. Estimates of both are invariably uncertain and rely on several complex assumptions that cannot be discussed here. Based on available information the world reserves of copper in ore have been estimated by the United States Bureau of Mines at 450 million short tons of copper (Table V-10). In addition, an estimated 1,600 million tons of copper is available in other global resources, including copper contained in oceanic manganese nodules. The United States accounts for 20 percent of known copper reserves and of other copper resources. The reserve classification includes all economically recoverable material in identified deposits. The other resource classification applies on an approximately equal division of deposits not yet discovered and to deposits from which the copper is not now economically recoverable[7].

Excluding deep sea resources, estimated at 400 million short tons of copper[8], the amount of copper estimated to exist in the rest of the world (i.e., outside the United States) comprises reserves of 360 million short tons and other resources of 880 million short tons. Six countries--in order of quantity, Chile, Canada, the U.S.S.R., Peru, Zambia, and Zaire--account for 69 percent of the rest of the world's reserves and 56 percent of other resources. Remaining reserves are divided among many other countries including Australia and Papua New Guinea, Finland, Iran, Japan, Panama, the People's Republic of China, the Philippines, Poland, the Republic of South Africa, Sweden and Yugoslavia.

The geographical distribution of reserves approximates the regional pattern of present production, with two exceptions. South America has a larger proportion of world copper reserves than of production, while the opposite is true for Europe, defined more broadly to include U.S.S.R. and Poland. Developing countries account for nearly 60 percent of world copper reserves--more than 1.5 times their share of world output.

TABLE V-10

WORLD COPPER RESERVES-RESOURCES
(millions of short tons of copper)

	Reserves	Other[a]	Total
North America:			
United States	90	320	410
Canada	40	130	170
Other	20	30	50
Total	150	480	630
South America:			
Chile	90	130	220
Peru	30	40	70
Other	10	70	80
Total	130	240	370
Europe:			
U.S.S.R.	40	90	130
Other	20	40	60
Total	60	130	190
Africa:			
Zaire	20	30	50
Zambia	30	70	100
Other	10	20	30
Total	60	120	180
Asia: Total	30	170	200
Oceania: Total	20	60	80
Sea nodules	--	400	400
World Total	450	1,600	2,050

NOTES: [a] Includes undiscovered (hypothetical and speculative) deposits.

SOURCE: U.S. Bureau of Mines, Copper, A Chapter from Mineral Facts and Problems, 1975 Edition, Preprint from Bulletin 667 (1976) p. 5.

It has been estimated that about 67 percent of the reserves are in currently producing mines, 13 percent in projects under construction, and 20 percent in other deposits for which sufficient information is available to assume with reasonable assurance that exploitation is feasible under present conditions[9]. The average grade is about 1 percent copper, although it ranges from 0.2 percent to almost 6 percent copper in individual deposits. The results also indicate that the average ore grade of producing mines is likely to decrease only slightly in the next 10-15 years[10].

It is extremely important to understand that reserves are not static but change over time as a function of prices, amount of exploration activity and technology. Prices, for example, directly affect the stock of reserves, since the lower the grade of the ore and the higher the cost of extraction, the higher must be the price for its recovery to be profitable.

C. UNITED STATES AND WORLD TRADE PATTERNS IN COPPER

There is considerable international trade in copper in all forms: ores, concentrates, blister, refined and fabricated products. Overall, the exporting countries have increased their degree of vertical integration and now export refined copper. The entry of Japan as an important importer (of concentrates, blister, and refined) has resulted in great diversification of trading patterns in recent years and a gradual decline in the absolute importance of trade in unrefined compared with refined metal.

1. Main Directions of World Trade

The bulk of the world's copper exports is from the developing countries to Europe, Japan and the United States, with smaller amounts from Canada, South Africa and Australia. The United States and Western Europe also export refined copper, but are net importers of copper overall. About 25 percent of world copper exports in 1974 was in the form of concentrates, 16 percent in blister copper and 59 percent in refined copper[11].

Trade in smelted copper has traditionally been mainly from Africa to Western Europe and from Latin America to the United States.

Tables V-11 through V-13 convey a summary of world trade patterns in copper.

Trade in concentrates flows mainly from the Philippines, Canada, Chile, and Indonesia, to Japan. Many other small producing countries also export to Japan. Most of the remainder flows from Chile, and several small exporters to West Germany. Both Japan and Western Europe have

TABLE V-11

WORLD BUREAU OF METAL STATISTICS: WORLD FLOW OF UNWROUGHT COPPER--1974--MINE PRODUCTION

Thousand metric tons

	EUROPE Belgium	Denmark	France	Germany F.R.	Irish Republic	Italy	Nether-lands	United Kingdom	Total E.E.C.	Austria	Finland	Greece	Norway	Spain	Sweden	Switzer-land	Yugo-slavia
MINE PRODUCTION	–	–	0·4	1·7	12·0	0·8	–	–	14·9	2·0	36·7	–	22·1	44·8	40·5	–	156·2
Exported to—																	
Belgium	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0·2	–	–
France	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Germany F.R.	–	–	0·3	–	–	–	–	–	0·3	0·3	–	–	0·3	1·0	–	–	2·6
Italy	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Netherlands	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
United Kingdom	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Finland	–	–	–	–	0·8	–	–	–	0·8	–	–	–	1·6	–	1·0	–	–
Greece	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Norway	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Spain	–	–	–	–	5·8	0·7	–	–	6·5	–	–	–	1·2	–	0·6	–	–
Sweden	–	–	–	–	5·4	–	–	–	5·4	–	–	–	9·0	–	–	–	–
Yugoslavia	–	–	–	1·3	–	–	–	–	1·3	–	–	–	–	–	–	–	–
Canada	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
U.S.A.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Argentina	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Japan	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
South Korea	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Australia	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Romania	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Bulgaria	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2·5	–	–
Germany Dem. Rep.	–	–	–	–	0·6	–	–	–	0·6	–	–	–	0·3	–	2·1	–	–
Poland	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Markets Unspecified	–	–	–	–	–	0·1	–	–	0·1	–	–	–	–	–	–	–	–
TOTAL EXPORTS	–	–	0·3	1·3	12·6	0·8	–	–	15·0	0·3	–	–	12·4	1·0	7·0	–	2·6
TOTAL IMPORTS	0·1	–	1·4	170·6	–	–	–	–	172·1	–	6·0	–	24·4	25·6	11·7	–	–
**Stock Change Consumption & Secondary Blister	– 70·4	– –	– 8·4	– 70·7	– –	– –	– –	– –	– 149·5	– 1·7	– 7·7	– –	+2·9 –	– 20·6	+4·3 19·6	– –	+1·8 –

	AMERICA Argentina	Brazil	Canada	Chile	Mexico	Peru	U.S.A.
MINE PRODUCTION	–	3·6	820·3	902·1	82·7	212·2	1 448·6
Exported to—							
Belgium	–	–	1·3	2·6	3·7	–	0·7
France	–	–	–	–	–	–	–
Germany F.R.	–	–	0·8	10·2	–	0·2	0·4
Italy	–	–	0·1	–	–	–	–
Netherlands	–	–	–	0·8	–	–	–
United Kingdom	–	–	1·4	–	–	–	–
Finland	–	–	0·2	4·2	–	–	0·2
Greece	–	–	–	1·6	–	–	–
Norway	–	–	24·4	–	–	–	–
Spain	–	–	–	6·9	–	–	0·8
Sweden	–	–	–	–	–	–	–
Yugoslavia	–	–	–	–	–	–	–
Canada	–	–	–	28·6	–	–	8·8
U.S.A.	–	–	20·3	–	1·0	6·7	–
Argentina	–	–	–	0·6	–	–	–
Japan	–	–	295·3	58·0	–	22·4	0·1
South Korea	–	–	–	3·6	–	–	–
Australia	–	–	–	4·6	–	–	–
Romania	–	–	–	2·7	–	–	–
Bulgaria	–	–	–	5·6	–	–	–
Germany Dem. Rep.	–	–	–	–	–	–	–
Poland	–	–	–	–	–	4·3	–
Markets Unspecified	–	–	–	10·1	–	0·8	0·2
TOTAL EXPORTS	–	–	343·8	155·0	4·7	34·4	11·3
TOTAL IMPORTS	–	–	40·1	–	–	–	90·0
**Stock Change Consumption & Secondary Blister	– –	– –	−8·5 –	+21·0 –	– –	– –	+86·3 72·8

	ASIA Cyprus	India	Indo-nesia	Japan	Philip-pines	Turkey
MINE PRODUCTION	11·6	20·1	64·6	82·1	225·3	40·7
Exported to—						
Belgium	–	–	–	–	9·0	–
France	–	–	–	–	–	–
Germany F.R.	0·7	–	12·1	–	–	–
Italy	–	–	–	–	–	–
Netherlands	–	–	–	–	–	–
United Kingdom	–	–	–	–	–	–
Finland	–	–	–	–	–	–
Greece	–	–	–	–	–	–
Norway	–	–	–	–	–	–
Spain	10·5	–	–	–	–	–
Sweden	–	–	–	–	–	–
Yugoslavia	–	–	–	–	–	–
Canada	–	–	–	–	–	–
U.S.A.	–	–	–	–	12·0	–
Argentina	–	–	–	–	–	–
Japan	–	–	51·6	–	211·6	–
South Korea	–	–	–	–	–	–
Australia	–	–	–	–	–	–
Romania	–	–	–	–	–	–
Bulgaria	–	–	–	–	–	–
Germany Dem. Rep.	–	–	–	–	–	–
Poland	–	–	–	–	–	–
Markets Unspecified	–	–	–	–	–	11·1
TOTAL EXPORTS	11·2	–	63·7	–	232·6	11·1
TOTAL IMPORTS	–	–	–	862·0	–	–
**Stock Change Consumption & Secondary Blister	+0·7 –	+0·1 –	+0·9 –	+22·2 127·3	– –	– –

	AFRICA Mauri-tania	R.S.A. & S.W. Africa	Uganda	Zaire	Zambia	AUSTRALASIA Australia	Papua New Guinea	Other Coun-tries	Free World Total	Communist Countries	World Total
MINE PRODUCTION	20·3	205·2	11·0	500·1	698·0	250·6	184·1	82·4	6 240·5	1 360·7	7 601·2
Exported to—											
Belgium	–	–	–	1·0	–	0·6	–	2·1	13·2	–	13·2
France	–	–	–	–	–	–	–	0·1	0·1	–	0·1
Germany F.R.	–	17·0	–	–	–	0·6	82·9	0·8	125·0	–	125·0
Italy	–	–	–	9·2	–	–	–	–	9·2	–	9·2
Netherlands	–	–	–	–	–	0·3	–	–	1·1	–	1·1
United Kingdom	–	–	–	–	–	0·1	–	–	1·5	–	1·5
Finland	–	–	–	–	–	–	–	–	8·7	–	8·7
Greece	–	–	–	–	–	–	–	–	1·6	–	1·6
Norway	–	–	–	–	–	–	–	–	24·4	–	24·4
Spain	6·6	–	–	–	–	–	–	2·6	29·6	–	29·6
Sweden	–	–	–	–	–	–	–	0·9	9·9	–	9·9
Yugoslavia	–	–	–	–	–	–	–	–	1·3	–	1·3
Canada	3·0	–	–	–	–	–	–	–	31·6	–	31·6
U.S.A.	–	–	–	–	–	–	–	2·0	42·0	–	42·0
Argentina	–	–	–	–	–	–	–	–	0·6	–	0·6
Japan	–	–	–	28·0	–	47·1	101·2	0·7	862·0	–	862·0
South Korea	–	–	–	–	–	–	–	–	3·6	–	3·6
Australia	–	–	–	–	–	–	–	–	4·6	–	4·6
Romania	–	–	–	–	–	–	–	–	2·7	–	2·7
Bulgaria	–	–	–	–	–	–	–	–	8·1	–	8·1
Germany Dem. Rep.	–	–	–	–	–	–	–	–	3·0	–	3·0
Poland	–	–	–	–	–	–	–	–	4·3	–	4·3
Markets Unspecified	13·6	–	–	60·0	–	0·1	–	10·6	121·5	–	121·5
TOTAL EXPORTS	23·2	17·0	–	98·2	–	48·8	184·1	20·7	1 284·4	–	1 284·4
TOTAL IMPORTS	–	–	–	–	–	–	–	19·5	1 260·0	10·1	1 270·1
**Stock Change Consumption & Secondary Blister	−4·1 –	−3·4 –	+2·7 –	– –	−11·0 –	+11·1 4·6	– –	−9·2 –	+172·7 400·1	−3·8 –	+168·9 400·1

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TABLE V-12

WORLD BUREAU OF METAL STATISTICS: WORLD FLOW OF UNWROUGHT COPPER--1974--SMELTER PRODUCTION

Thousand metric tons

	EUROPE																	AMERICA							ASIA						AFRICA					AUSTRALASIA						
	Belgium	Denmark	France	Germany F.R.	Irish Republic	Italy	Nether-lands	United Kingdom	Total E.E.C.	Austria	Finland	Greece	Norway	Spain	Sweden	Switzer-land	Yugo-slavia	Argen-tina	Brazil	Canada	Chile	Mexico	Peru	U.S.A.	Cyprus	India	Indo-nesia	Japan	Philip-pines	Turkey	Mauri-tania	S.W. Africa	Uganda	Zaire	Zambia	Australia	Papua New Guinea	Other Coun-tries	Free World Total	Communist Countries	World Total	
SMELTER PRODUCTION	[illegible]	-	[illegible]	[illegible]	-	-	-	-	[illegible]	[illegible]	[illegible]	-	[illegible]	[illegible]	[illegible]	-	[illegible]	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	[illegible]	-	[illegible]	-	[illegible]	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	[illegible]	[illegible]	[illegible]	[illegible]	SMELTER PRODUCTION
Exported to —																																										Exported to —
Belgium	-	-	[illegible]	[illegible]	-	[illegible]	-	-	[illegible]	-	[illegible]	-	-	-	-	-	-	-	-	-	[illegible]	-	[illegible]	[illegible]	-	-	-	-	-	-	-	[illegible]	-	[illegible]	[illegible]	-	-	-	[illegible]	[illegible]	[illegible]	Belgium
France	[illegible]	-	-	-	-	-	-	-	[illegible]	-	-	-	-	-	-	-	[illegible]	-	-	-	[illegible]	-	-	-	-	-	-	-	-	-	-	-	-	[illegible]	[illegible]	-	-	-	[illegible]	[illegible]	[illegible]	France
Germany F.R.	[illegible]	-	[illegible]	-	-	[illegible]	-	-	[illegible]	-	-	-	[illegible]	-	-	-	-	-	-	-	[illegible]	-	[illegible]	-	-	-	-	-	-	-	-	[illegible]	[illegible]	[illegible]	-	-	-	[illegible]	[illegible]	[illegible]	[illegible]	Germany F.R.
Italy	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	[illegible]	[illegible]	-	-	-	-	-	-	-	-	-	-	[illegible]	-	-	-	-	-	[illegible]	-	[illegible]	Italy
Netherlands	[illegible]	-	-	[illegible]	-	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-	-	-	-	-	-	-	[illegible]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	[illegible]	-	[illegible]	Netherlands
United Kingdom	-	-	-	[illegible]	-	-	-	-	[illegible]	-	-	-	-	-	-	-	-	-	-	-	[illegible]	-	[illegible]	[illegible]	-	-	-	-	-	-	-	[illegible]	[illegible]	[illegible]	[illegible]	-	-	[illegible]	[illegible]	-	[illegible]	United Kingdom
Austria	-	-	-	[illegible]	-	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-	-	-	-	-	[illegible]	-	-	-	-	-	-	-	-	-	-	[illegible]	-	-	-	-	-	-	[illegible]	-	[illegible]	Austria
Portugal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	[illegible]	-	-	-	[illegible]	-	[illegible]	Portugal
Spain	-	-	[illegible]	[illegible]	-	-	-	-	[illegible]	-	-	-	-	-	-	-	-	-	-	-	[illegible]	-	-	-	-	-	-	-	-	[illegible]	-	-	-	-	[illegible]	-	-	-	[illegible]	-	[illegible]	Spain
Yugoslavia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	[illegible]	-	-	-	-	-	-	-	-	-	-	-	-	-	[illegible]	-	-	-	[illegible]	-	[illegible]	Yugoslavia
Canada	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	[illegible]	-	[illegible]	Canada
U.S.A.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	[illegible]	[illegible]	[illegible]	-	-	-	-	-	-	-	-	[illegible]	[illegible]	-	[illegible]	-	-	[illegible]	[illegible]	-	[illegible]	U.S.A.
Mexico	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	[illegible]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	[illegible]	-	[illegible]	Mexico
Japan	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	[illegible]	[illegible]	[illegible]	-	-	-	-	-	-	-	-	[illegible]	[illegible]	-	[illegible]	[illegible]	-	-	[illegible]	-	[illegible]	Japan
Germany Dem. Rep.	-	-	-	-	-	-	-	-	-	-	-	-	[illegible]	-	-	-	-	-	-	-	[illegible]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	[illegible]	-	[illegible]	Germany Dem. Rep.
Hungary	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	[illegible]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	[illegible]	-	[illegible]	Hungary
Poland	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	[illegible]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	[illegible]	-	[illegible]	Poland
Romania	-	-	-	-	-	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	[illegible]	-	[illegible]	Romania
China	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	[illegible]	-	[illegible]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	[illegible]	-	[illegible]	China
Markets Unspecified	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	[illegible]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	[illegible]	[illegible]	-	[illegible]	Markets Unspecified
TOTAL EXPORTS	[illegible]	-	[illegible]	[illegible]	-	[illegible]	-	-	[illegible]	-	[illegible]	-	[illegible]	-	-	-	[illegible]	-	-	-	[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	-	[illegible]	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	[illegible]	[illegible]	[illegible]	[illegible]	TOTAL EXPORTS
TOTAL IMPORTS	[illegible]	-	[illegible]	[illegible]	-	[illegible]	-	[illegible]	[illegible]	[illegible]	-	-	-	[illegible]	[illegible]	-	[illegible]	-	-	-	-	-	-	[illegible]	-	-	-	[illegible]	-	-	-	-	-	-	-	-	-	[illegible]	[illegible]	[illegible]	[illegible]	TOTAL IMPORTS
**Stock Change Blister	[illegible]	-	[illegible]	-	-	-	-	[illegible]	[illegible]	-	[illegible]	-	[illegible]	[illegible]	[illegible]	-	[illegible]	-	-	[illegible]	[illegible]	-	[illegible]	[illegible]	-	[illegible]	-	[illegible]	-	[illegible]	-	[illegible]	-	-	[illegible]	[illegible]	-	[illegible]	[illegible]	-	[illegible]	**Stock Change Blister
Refined from scrap	[illegible]	-	-	[illegible]	-	[illegible]	-	[illegible]	[illegible]	[illegible]	-	-	-	[illegible]	-	-	[illegible]	-	[illegible]	[illegible]	-	[illegible]	-	[illegible]	-	-	-	-	-	-	-	-	-	-	-	[illegible]	-	-	[illegible]	[illegible]	[illegible]	Refined from scrap
Direct use of blister	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Direct use of blister

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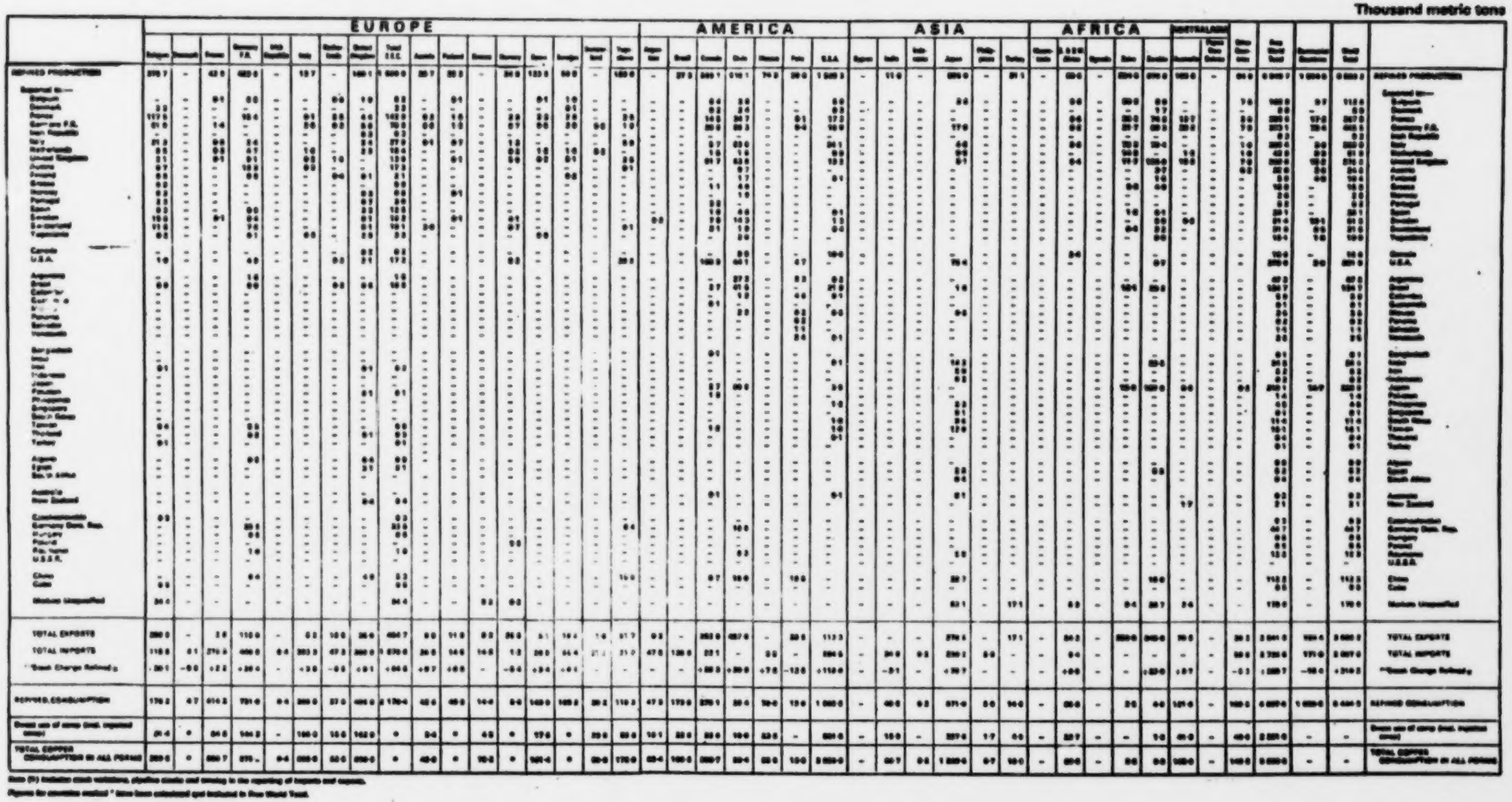
TABLE V-13

WORLD BUREAU OF METAL STATISTICS: WORLD FLOW OF UNWROUGHT COPPER--1974--REFINED PRODUCTION

Thousand metric tons



EUROPE AMERICA ASIA AFRICA

TOTAL EXPORTS

TOTAL IMPORTS

REFINED CONSUMPTION

TOTAL COPPER CONSUMPTION IN ALL FORMS

smelting and refining capacity several times their mine output, and import substantial amounts of concentrates and blister. In the past, a significant portion of the output of the mines owned by private international firms was sold to parent companies or affiliates of the mining firms. However, this pattern has been changing with the nationalization of the private firms in the CIPEC countries and the assumption of the marketing function by the governments of these countries.

The leading exporters of unrefined blister copper are Germany,(FR), Chile, Peru, Zaire, and S.W. Africa.

The list of leading exporters of refined copper includes such countries as Canada, Chile, United States, Zaire, Zambia, Germany, (FR), Belgium-Luxembourg, Australia, the United Kingdom and Japan.

The leading exporters of refined copper all have diversified markets but Belgium and Zaire export mainly to members of the EEC. Zambia's major markets are the United Kingdom, countries in Continental Europe, and since the mid-1960's, Japan. Canada's most important markets are the United Kingdom and the United States, while Chile exports mainly to Continental Europe. United States exports are highly diversified but sales to Europe predominate.

West Germany imports all of its primary copper needs, a majority in refined form. It is also one of the leading importers of scrap.

Neither Belgium nor the United Kingdom has very large smelter outputs but the former is a large refiner based on imported blister and some scrap, while the latter is also a large refiner based mainly on scrap plus some imported blister. Belgium, however, exports much of its refinery output while the United Kingdom requires large net imports of refined copper. Refined imports supply three quarters or more of the United Kingdom's primary copper consumption (smelted imports supply the remainder), and slightly more than half of total copper usage.

Other leading consuming countries in Europe, including France, Italy and the Netherlands, import most of their refined copper requirements in that form, supplemented by small local refined production from scrap. Sweden is an important primary producer but also imports refined metal.

Most of the copper exported by the developing countries is sold under contract to smelters, refineries, or fabricators in the developed countries. The pattern of world trade in concentrates tends to be governed by long-term contracts which may call for deliveries over periods up to 15 or 20 years, financial arrangements providing for repayment of loans in concentrates, and ownership ties between the mining and processing companies. Also, smelters are frequently geared to processing particular concentrates.

Long-term contracts for the sale of concentrates or blister have important advantages for both the mines and the smelters or refineries with which they are negotiated. Smelters and refineries in Japan and Europe which lack domestic sources of raw materials want to be assured of raw material supplies; in the case of private or nationalized mines that are not vertically integrated, long-term contracts for the sale of concentrates are frequently important factors in the decision to construct the mine[12].

By contrast, trade in refined copper is for the most part based on short-term contracts of one-to-twelve month duration. While more competitive, it is also influenced by nonprice factors such as ownership ties, technical assistance and marketing contracts, such as that between Belgium and Zaire, and long standing buyer-seller relationships. Ownership ties between producing and consuming countries have been declining, and, even where they exist, governments of producing countries have taken a more active role in marketing and are attempting to diversify their markets. Other nonprice factors, such as strikes, transportation problems, natural disasters in the producing countries, and recessions in the consuming countries, frequently affect the pattern of trade in refined copper. The bulk of the world's refined copper is sold directly by the producers to fabricators and semifabricators; only marginal amounts are sold through the London Metal Exchange (LME) and the New York Commodity Exchange (COMEX)[13]. The price for these transactions, however, is related by some formula to a market price, usually the LME price.

Fabricators and semifabricators also tend to buy additional refined copper from dealers or merchants. Merchants, in turn, deal extensively with independent refineries which are not associated with large integrated firms. They may buy scrap for sale to refineries and purchase output from refineries not committed under contract for sale to fabricators or for them to hold as stocks[14].

Since the United States copper industry is generally more integrated than in the rest of the world, merchants are somewhat less important in the United States than abroad[15].

It is difficult to measure the extent of vertical integration of primary copper producers forward into copper fabricating. As a generalization, primary producers in North America and Japan have important fabricating operations, refiners in Europe are partially integrated forward, and those in other producing countries have very little fabricating capacity. Further, in general the structure of the copper consuming industries appears to be broadly similar in all larger industrial countries. In each major copper-using sector (rolling or brass mills, wire mills, and foundries), national industries are characterized by a small number of large firms and a much larger number of medium to small firms. The larger firms in the United States and Japan are in many cases affiliated with primary producers while some fabricators in the United Kingdom and Continental Europe are affiliated with domestic refineries. The majority of smaller fabricators in all countries appear to be independent or primary producers. The important point here is that a substantial market for refined copper which exists in most industrial countries is not captive to primary producers.

2. United States Trade Patterns

The United States is virtually or nearly self-sufficient in copper. As shown in Table V-14, the United States has experienced a heavy dependence on foreign sources of copper only in such years as 1950, a Korean build-up year, or 1972, and extreme "demand-crunch" year. Otherwise, net United States imports have remained well under ten percent of total domestic consumption of refined copper[16].

Nearly half of United States copper imports are in the form of refined copper as shown in Table V-15 (from mainly Canada, Japan and Chile)[17] with smaller amounts imported in the form of blister and cement copper, or in the form of ore and concentrates[18].

Similarly, the bulk of United States exports is in the form of refined copper (Table V-16). For example, in 1974 most of the United States exports was destined to such countries as Brazil, France, West Germany, Italy and the United Kingdom[19].

In summary, although the United States has been nearly self-sufficient in copper, except in certain years coinciding with military developments or unusual "demand-crunch" periods, the United States is both a leading importer and exporter of copper. The impact of domestic environmental regulations on the United States copper industry should therefore be examined with close attention to their international economic implications, affecting the structure of the world copper industry, international trade patterns, and the role of the United States in the world copper industry.

TABLE V-14

TRENDS IN UNITED STATES COPPER CONSUMPTION AND TRADE, 1950-1975

(short tons)

Years	Total refined consumption	Total imports of refined and unrefined copper (copper content)[a]	Total exports of refined and unrefined copper[b] (copper content)	Net Trade (net imports)	Net trade as Percent of total refined consumption
1950	1,424,434	690,389	154,622	535,767	37.6
1960	1,599,700	524,344	503,733	20,611	1.3
1970	2,043,303	392,480	299,304	93,176	4.6
1971	2,019,507	359,479	214,215	145,264	7.2
1972	2,238,867	415,618	225,165	190,453	8.5
1973	2,437,048	417,434	262,552	154,882	6.4
1974	2,194,168	607,992	189,851	418,141	19.1
1975	1,536,694	324,126	227,273	96,853	6.3

NOTES: [a] Includes refined copper, ore and concentrate, blister and cement copper, matte and scrap.

[b] Includes only refined copper, ore and concentrate, etc. (unrefined copper), and scrap; exclusive of copper semimanufactures or manufactured copper products (e.g., plates, sheets, strips, wire, etc.).

SOURCES: U.S. Bureau of Mines:
1950: Minerals Yearbook, Vol. I, Metals and Minerals (Except Fuels), 1952, pp. 360-371;
1960: Minerals Yearbook, Vol. I, Metals and Minerals (Except Fuels), 1962, pp. 499-509;
1970: Minerals Yearbook, Vol. I, Metals, Minerals and Fuels, 1971, pp. 485-491;
1971-1975: Mineral Industry Surveys, Copper, in 1972, 1973, 1974 and 1975 (separate reports).

TABLE V-15

UNITED STATES IMPORTS OF COPPER, BY TYPE, 1971-1975
(copper content, short tons)

	1971	1972	1973	1974	1975
Refined	163,988	192,380	201,513	313,568	146,807
Ore and Concentrate	30,848	53,653	42,135	53,422	64,879
Blister and Cement copper	156,744	157,430	154,104	207,828	88,949
Matte	440	1,367	746	1,944	9,093
Scrap	7,459	10,788	18,936	31,230	14,398
TOTAL	359,479	415,618	417,434	607,992	324,126

SOURCE: U.S. Bureau of Mines, Mineral Industry Surveys, Copper in 1972, 1973, 1974 and 1975 (separate reports).

TABLE V-16

UNITED STATES EXPORTS OF COPPER, BY TYPE, 1971-1975

(short tons)

Type	1971	1972	1973	1974	1975
Refined Copper	187,654	181,494	189,396	126,526	172,419
Ore, concentrates, etc. (copper content)	8,126	26,231	30,870	21,983	9,853
Old and scrap	18,435	17,440	42,286	41,342	45,001
Ash and residues	-	9,381	15,087	8,233	6,601
Pipes and tubes	1,249	1,142	7,744	6,738	2,200
Plates, sheets and strips	287	279	474	793	186
Semi-fabricated forms n.e.c.	7,746	6,299	7,431	8,332	9,517
Wire: Bare	1,925	2,767	5,196	5,632	3,720
Insulated	24,590	28,660	40,046	62,514	79,631

SOURCE: U.S. Bureau of Mines, Mineral Industry Surveys, Copper in 1972, 1973, 1974 and 1975 (separate reports).

D. CHANGES IN THE STRUCTURE OF THE WORLD COPPER INDUSTRY

Significant changes in the structure of the world copper industry have occurred during the postwar period. First, the copper industry has become not only more diversified geographically with the emergence of new producing countries but also relatively less concentrated, as new firms have entered the industry to expand the industry's production significantly during this period. World mine production of copper in 1973/1974 included substantial output from countries--such as Peru, the Philippines, the Republic of South Africa, Australia, Papua-New Guinea and Indonesia--which were not major sources in 1950. Further, these new sources are not controlled by any of the major companies which dominated the industry in 1950 (e.g., Anaconda, operating in the United States, Mexcio and Chile; Kennecott, operating in the United States and Chile; Phelps Dodge, operating in the United States alone; Rhodesian Selection Trust, operating in what was then known as Northern Rhodesia; Rhodesian Anglo-American, also operating in Northern Rhodesia; Union Miniere, operating in what was then known as the Belgian Congo; and International Nickel, operating in Canada). Despite these changes, however, the industry remains highly concentrated in the individual copper producing countries.

Second, the nationalization of copper mining and processing operations in major copper exporting developing countries has brought about a significant shift in ownership patterns in the world copper industry in recent years. As the governments of these countries have exerted increasing control over, and participation in, the production and marketing of copper, the role of the international mining companies in exploration and development has declined. This realignment in ownership patterns has significant potential implications for the future, involving prospects for cartelization and international commodity stabilization agreements.

1. Changes in Ownership Patterns

Orris Herfindahl estimated that in 1947 four mining firms accounted for about 60 percent of world output (excluding the U.S.S.R.) and eight firms accounted for 77 percent of world output. By 1956 these percentages had declined to 49 and 70 percent respectively[20]. All of these companies were privately owned and most of the stock was held by residents of the United States, Canada and the principal Western European countries. In 1974 the four largest private copper producers--Kennecott, Phelps Dodge, Newmont and Anaconda--had majority ownership interest in 17 percent of the free world mine copper output, and eight privately-owned companies had a major interest in about 28 percent of the free world mine copper output[21]. Ten other privately-owned companies are majority owners of an additional 12.5 percent of the free world copper output[22].

The majority of wholly-owned government mining enterprises (e.g., in Chile, Peru, Zaire, Zambia, Turkey, India, Uganda) accounted for about 34 percent of the free world mine output in 1974. According to Sir Ronald Prain, in 1970 about 43 percent of copper producing capacity in the non-Communist world was owned in whole or in part by governments[23]. Moreover, governmental ownership of the copper industry is heavily concentrated in the copper exporting countries--mainly the CIPEC countries. In some countries, including Zambia, Mexico and Australia (Mt. Isa), large international mining companies have reduced their equity holdings from a majority to a minority position in recent years.

Mines in Chile, Zambia, Peru and Zaire were initially developed by large foreign companies. In recent years, the governments involved have exerted increasing control over, and participation in ownership of, these mines. Nationalization of United States interests in Chile began in 1967 when the Chilean Government took over a 51-percent interest in the El Teniente mine of the Braden Copper Company, a wholly owned subsidiary of the Kennecott Copper Corporation. In 1969 an agreement was reached between The Anaconda Company and the Chilean Government whereby Chile acquired 51 percent of Anaconda's Chuquicamata and El Salvador properties in 1970. Complete nationalization of United States copper investments in Chile was a proclaimed objective of President Allende, who was inaugurated in November 1970. He met this objective during 1971, and nationalization continued to be the policy of the military junta that took power in September 1973[24].

Effective January 1, 1970, the Zambian Government acquired a 51-percent interest in the Zambian copper industry. Anglo-American Corporation and Roan Selection Trust, Ltd. (RST), owned the remaining interest and operated the major copper mines. Over 80 percent of the shares of RST were owned by United States interests. In 1973 the President of Zambia announced measures that included the intent for Zambia to assume complete ownership of the major mines and to establish a marketing company for the sale of the copper produced. In 1974 the Zambian government terminated both the management and the sales contracts with the Anglo-American group and Amax, the former majority owners (now 49 percent owners). In that same year the Peruvian government nationalized Cerro de Pasco, the second largest copper producer after Southern Peru Copper Company (which owns Toquepala and Cuajone). The new copper refinery at Ilo is wholly government-owned and operated. Finally, in 1975 the government of Zaire renegotiated its technical assistance and sales agreements with the Belgium firm SGM (an affiliate of Union Miniere) so that operations and sales of Gecamines output are entirely under government control.

To summarize, 21 private companies have a majority interest in mines producing about 44 percent of total copper production in the market economies (including Yugoslavia), and another 34 percent is produced by majority-owned government enterprises in eight important copper producing countries. Most of the remaining 22 percent is produced by a fairly large number of privately-owned companies, some of which have a minority government participation. Among the Sino-Soviet Block countries, which account for slightly over 20 percent of total world mine production (see Table V-6), 75 percent is produced in the U.S.S.R. and most of the remainder in Poland, China and Bulgaria.

Majority private ownership in copper mines does not carry with it full control over production and marketing. For example, although the majority of Peruvian output is produced by a foreign-owned firm, Southern Peru Copper Corporation (SPCC), Peru's mineral output is marketed by MINPECO, a government agency. In all of the CIPEC member countries--Chile, Indonesia, Peru, Zaire and Zambia--the government exercises control over marketing and production in accordance with CIPEC guidelines. Indonesia became a full member in November 1975. (Australia and PNG are Associate Members of CIPEC and are not bound by CIPEC's decisions). In 1974 the original CIPEC members accounted for 38 percent of world mine copper production and about 62 percent of world copper exports. If Indonesia and the new Associate Members of CIPEC are included, these shares rise to 46 and 72 percent respectively.

2. Changes in Industry Concentration by Country[25]

The copper industry's worldwide geographical concentration is paralleled by its industrial concentration. Both reflect the fact that most of the world's copper is produced from low-grade deposits. Such deposits can be exploited economically only on a large scale. Remarkable changes have occurred during the postwar period in the structure and ownership patterns of the world copper industry as described below.

- United States: A large portion of the copper in the United States is produced by three companies--Anaconda, Kennecott and Phelps Dodge--who account for 54.6 percent of total United States mine production in 1974 (57.7 percent in 1973). Nine companies (i.e., Kennecott, Anaconda, Phelps Dodge, Magma, Duval, Cyprus, Asarco, Copper Range and Inspiration) account for 91.5 percent of United States mine production (87.2 percent in 1973). Most of the nine companies also smelt all of their own output. Seven primary producers in the United States (i.e., Asarco, Kennecott, Phelps Dodge, Anaconda, Magma and Inspiration) refine copper, accounting for about 84 percent of United States refining capacity in 1974. United States smelting and refining companies also process a limited amount of foreign concentrates and imported blister copper.

As discussed in Chapter III, the structure of the United States domestic copper industry has changed appreciably during the postwar period, with the emergence of new companies, the growth of others, and shifts in the degree of backward or forward integration of various companies.

- Canada: There are about 20 important copper mining companies in Canada, with seven companies producing about 56 percent of the total output in 1974. Only about 61 percent of Canada's mine production was smelted in Canada in that year. However, Canada's refining capacity was equal to about 75 percent of her mine output in 1974. Canadian smelting capacity is owned by four firms--Falconbridge, Noranda, Hudson Bay and International Nickel (INCO). Refining capacity is owned by two firms--Canadian Copper and INCO.

  The structure of the copper industry in Canada has changed considerably during the postwar period. INCO, whose production in 1955 accounted for 41.1 percent of the national total was responsible for only 21.8 percent in 1975. Hudson Bay, whose share of Canada's total mine production was 14.3 percent in 1955 claimed only 8.2 percent in 1975. Canadian companies that produced no copper in 1950, but that had very substantial production in 1973, included Bethlehem Copper, Craigmont, Texasgulf, Gibralter, Lornex, and Utah Mines Ltd.

- Chile: In Chile the bulk of the copper is produced by mines nationalized in 1972. Most of Chile's mine output is smelted in Chile and about 60 percent of Chile's output is refined in that country.

  The Anaconda and Kennecott properties in Chile were taken over by the Chilean government in two stages, first partially under President Frei and then completely under President Allende. Mine production has since been in the hands of the government-owned Corporacion del Cobre, which thereby became the world's largest single producer and seller of copper. In addition to the Anaconda and Kennecott mines it also acquired the Andina mine developed by Cerro Corporation in the late 1960's.

- **Zambia:** In Zambia all copper is produced by two mining companies, Roan Consolidated and Nchanga Consolidated, owned 51 percent by the government. Zambia has smelting and refining capacity for nearly all of her mine output.

- **Zaire:** In Zaire the government-owned mining company, Gecamines, which took over the Union Miniere mines, produced 92 percent of the mine output in 1974 with a small but growing output produced by the Japanese firm, Sodimiza. Sodimiza ships concentrates, but all of the Gecamines' output is smelted and 45 percent is refined in Zaire.

- **Peru:** The Toquepala mine of the Southern Peru Corporation, in which Asarco is the largest shareholder but in which Cerro-Marmon, Phelps Dodge and Newmont also hold interests, currently accounts for over half of mine and smelter production in Peru and this proportion is expected to rise to 75 percent with the scheduled full operation of the Cuajone mine in 1977. The remainder is produced by government-owned mines and several small private mines. By 1977 about half of Peru's mine and smelter production will be refined in government-owned refineries. The Peruvian Government through Centromin now operates the former Cerro properties which in 1950 accounted for the bulk of Peru's total production.

- **Australia:** In Australia 57 percent of the mine copper output in 1974 was accounted for by the Mt. Isa mine, which is owned by M.I.M. Holdings and in which Asarco has 49 percent interest. Three mines, including Mt. Isa, produced 77 percent of total output. Australia has smelter and refinery capacity for nearly 80 percent of its mine output.

- **South Africa:** Nearly 85 percent of South Africa's mine copper is produced by three private firms, owned largely by international mining companies, Rio Tinto Zinc (RTZ), Newmont and U.S. Steel. South Africa has smelter capacity for over 80 percent of her mine output, but has refining capacity for less than half of her mine output.

  The largest South African production is from the Palabora mine, which is controlled by Rio Tinto Zinc and in which Newmont is a minority shareholder. Palabora had not been developed in 1950. O'okiep, controlled by Newmont, the second largest South African producer in 1973, was the principal source of the country's copper production in 1950.

- The Philippines: Philippine mine output is produced by six private mining companies, one of which, Atlas Consolidated, produces about 40 percent of the total. There are no smelters or refineries in the Philippines but one is in the planning stage.

- Papua New Guinea (PNG): PNG's output is produced solely by the majority foreign-owned firm, Bougainville Copper Ltd. (a subsidiary of Conzinc Rio-Tinto which, in turn, is a subsidiary of RTZ). All output is shipped abroad in the form of concentrates.

In addition, Indonesia has since 1972 entered the ranks of the copper producers. Still further geographical diversification of copper mine production is in prospect. The Iranian Government is bringing a very large mine, Sar Chesmeh, into operation in 1977. Mexico's production, which was 94,000 short tons in 1975, will be substantially increased when the Caridad mine of Mexicana de Cobre is brought into production in the course of the next two or three years. Further, a major copper deposit has been identified in Panama, where the Panamanian Government, in conjunction with Texasgulf, is now undertaking a feasibility study.

In conclusion, in spite of changes in ownership patterns, industry growth and geographical diversification, copper mining and processing in individual countries or areas remains characterized by a relatively high degree of concentration. However, little can be concluded a priori about possible implications of industry structure for industry behavior and market competition without consideration of other market forces that affect industry behavior. Factors of interest include the extent of vertical integration into fabricating, the importance of trade barriers and transportation costs as constraints to international trade, entry conditions facing potential new producers, pricing constraints imposed by secondary metal and the threat of substitution away from copper, and government intervention in markets.

CHAPTER V

NOTES

1. 1974 is the base year used in this study.

2. It should be noted that United States share of world production in 1974 was affected by strikes. In 1973, when there were not strikes, United States accounted for 20.5 percent of mine production, 21.2 percent of smelter production and 24.7 percent of refinery production.

3. During the November 17-19, 1975 meeting in Lima, Peru, the four founding members accepted Indonesia as a full member and Australia and Papua New Guinea as nonvoting associate members (not subject to CIPEC control directives). The new membership increases CIPEC participation in internationally traded copper to more than 72 percent.

4. United States Bureau of Mines, Copper, a chapter from Mineral Facts and Problems, 1975 Edition, Preprint from Bulletin 667 (1976), p. 4.

5. United Nations, Department of Economic and Social Affairs, The Future of the World Economy, prepared by a research team led by Anne P. Carter, Wassily Leontief and Peter Petri, Preliminary (United Nations, 1974). p. 21.

6. Ibid.

7. United States Bureau of Mines, Copper (Mineral Facts and Problems), op. cit., p. 6.

8. Ibid. The assigned 400 million short tons of copper in ocean nodules can only be considered tentative until the data base for this emerging resource is improved. Ocean nodules occur in varying concentrations and tenor at many ocean sites. The most valuable identified deposits are within a belt in the Pacific Ocean bounded by the Tropic of Cancer, the Equator, the International Date Line, and the Central American coast line. The nodules in this area lie on the bottom sediments in water depths of about 15,000 feet. Although manganese is the major metal constituent in the nodules, the principal metals of economic interest are nickel, copper, and cobalt, which have been reported to grade 1.3, 1.1, and 0.25 percent, respectively, in some of the better deposits.

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(Continued)

9. United Nations, Centre for Natural Resources, Energy and Transport, "Recent Global Developments in the Mineral Sector", *Natural Resources and Energy*, Vol. 1, No. 5 (April, 1977), p. 4.

10. *Ibid*.

11. Data are from Statistical Bulletin, 1975, CIPEC, Paris, 1976.

12. For example, the ability of Bougainville Copper Ltd. (BCL) to negotiate long-term contracts for the sale of concentrates for foreign smelters in 1969 played an important role in the ability of the company to mobilize financing for the mine.

    This and the following few points made here are drawn from an unpublished manuscript by Raymond F. Mikesell, entitled "The Nature of the World Copper Market for Copper" (Eugene, Oregon: University of Oregon, June, 1974), pp. 5-6.

13. Refer to Chapter VIII for a discussion of the LME and the COMEX.

14. For a discussion of the role of merchants in the copper market, see Ferdinand E. Banks, The World Copper Market: An Economic Analysis (Cambridge, Massachusetts: Ballinger Publishing Company, 1974), pp. 41-43.

15. *Ibid*., p. 43.

16. These figures would be even less if we defined domestic copper consumption to include directly consumed scrap.

17. Figures for 1974 were as follows: from Canada 118,431 short tons; Japan 73,053 short tons; Chile 66,549 short tons. See United States Bureau of Mines, Mineral Industry Surveys, Copper in 1974 (April 8, 1975), p. 6.

18. Although some of this material enters the United States as imports, it is held in "bond" only to be shipped abroad for further processing. This historically has applied especially to unrefined copper "imports" from Chile. Consequently, the import and export statistics, thus subject to some degree of "noise", should not be taken too literally.

    In 1974 the major sources of United States imports of copper, by type, were as follows (copper content, short tons):

Ore and Concentrate:		Blister:	
(from) Canada	19,917	(from) Chile	65,093
Philippines	14,244	Peru	94,686
		Republic of South Africa	37,211

NOTES
(Continued)

See United States Bureau of Mines, Mineral Industry Surveys, Copper in 1974 (April 8, 1975), p. 6.

19. Ibid., p. 7.

20. Orris C. Herfindahl, Copper Costs and Prices: 1870-1957, published for Resources for the Future, Inc. (Baltimore: The Johns Hopkins Press, 1959), p. 165.

21. The eight companies are Anaconda, Asarco, International Nickel, Kennecott, Mt. Isa, Newmont, Phelps Dodge and Rio Tinto Zinc (RTZ).

22. These ten companies include Atlas, Freeport, Inspiration, Lornex, Noranda, Texasgulf, Cyprus, Duval, Palabora, and Copper Range.

23. Sir Ronald Prain, Copper, The Anatomy of An Industry (London: Mining Journal Books, 1975).

24. United States Bureau of Mines, Copper (Mineral Facts and Problems), op. cit., p. 3.

25. This discussion draw, in part, upon Simon D. Strauss, "Competition in the Nonferrous Metal Markets", Presentation before the Annual Meeting of the American Institute of Mining, Metallurgical and Petroleum Engineers, Atlanta, Georgia (March 9, 1977).

VI. SUPPLY

A. INTRODUCTION

This chapter is devoted to the economics of the supply of copper and forms the first in a series of three chapters covering, respectively, copper supply, demand, and prices. This chapter attempts to convey an understanding of a number of key aspects of the supply response of primary copper producers and tries to highlight the central analytical issues in studying the dynamics of copper supply quantitatively.

Accordingly, the remainder of this chapter is organized into four sections. The first section discusses the sources of copper supply and gives an overview of the long-run supply behavior of the primary producers. This section contains a condensed exposition of the fundamental principles and findings of the economics of exhaustible resources which, of course, includes copper. The objective of this section is to provide a general perspective for the following two sections which are concerned with trends in capacity growth and costs of production. The final section presents a critical review of the analytical approaches used in the past in quantitatively studying the supply side and notes, broadly, the methodological approach employed in this study.

There are three major sources of copper: sulfide copper, oxide copper, and scrap. Primary copper is mainly produced through the exploitation of large, low-grade sulfide deposits. We expect sulfide reserves to continue to play a dominant role in meeting growing demand in the foreseeable future. At present, total United States copper reserves comprise about one-fifth of total world reserves. Current production is based principally on sulfide deposits.

In theory, the existing reserves will continue to be exploited as long as the scarcity rent of the resource (i.e., market price minus extraction cost) will grow at a rate approximating the interest rate (i.e., the rate of social time-preference). Also, in principle, no high cost deposit will be used until the low-cost resource is exhausted.

The supply of copper from the available reserves is characterized by long adjustment periods. Typically, investments are large, have long productive life-expectancy, and are perceived to be highly risky in view of cyclical fluctuations in copper prices. Because of the cyclicality of the copper industry, the threat of long-run substitution from other materials, competition from both the secondary and foreign producers plus other factors, investments are made with an expected long-run target rate of return. This defines the industry's "incentive price", that is, the price at which the firms would be willing to stay in business over the long-run, where revenues are sufficient to cover full costs, including a return on investments high enough to attract new capital. This is consistent with the hypothesis that the long-run price of copper tends to equal the long-run economic cost of copper or the price sufficient to induce continued investment at all stages of production.

Of the four stages of primary copper production--mining, milling, smelting and refining--, the smelting stage is, of course, the major interest in this study. During the postwar period, domestic smelter capacity growth has occurred mainly through incremental additions to existing smelter operations, rather than the construction of new "grassroots" (or greenfield) smelters.

The domestic copper industry is believed to have experienced sharp increases in production costs in recent years because of a combination of factors including declining ore grades, stagnant productivity, and steep rises in energy and other factor costs, and pollution control costs.

The quantitative analysis of the supply behavior of primary copper producers has in the past been studied, such as in econometric models of the copper industry, typically by taking the "supply curve" approach- We find such an approach seriously deficient, in terms of its microeconomic theoretical underpinnings, its ability to explain the adjustment process in supply, through new capacity creation, and in terms of the econometric difficulties typically encountered in supply function estimation. In view of our serious reservations about the "supply curve" approach, this study addresses the problem by simultaneously considering market conditions, investment for capacity expansion, production costs, and the industry's financial performance within an integrated, unified framework. Such an approach captures the evolving dynamics of supply behavior over time.

B. SOURCES OF COPPER SUPPLY AND LONG-RUN SUPPLY BEHAVIOR IN THE UNITED STATES COPPER INDUSTRY

This section addresses four areas which provide the broad context for the next two sections concerned directly with the pattern of smelter/refinery capacity growth in the past and costs of copper production. These four areas are the sources of copper supply, copper reserves, the economic theory of exhaustible resources, and the observed long-run supply behavior of the United States primary producers. Since, these topics are not only highly interrelated but also quite broad, an attempt is made here to touch only upon the most important points.

1. Sources of Copper Supply

There are three major domestic sources of copper supply: sulfide copper, oxide copper and scrap. Figure VI-1 depicts these three major supply channels and the relationships among them.

Sulfide copper minerals form the bulk of the copper reserves in the United States and are currently the largest source of primary copper produced domestically. This production is achieved by the exploitation of large, low-grade deposits on a large scale using the conventional techniques described in Chapter II through a four-stage production process, namely mining, milling, smelting and refining. As noted in Chapter III, we expect sulfide reserves to continue to play a dominant role in meeting the growing demand for copper.

Oxide mineral deposits represent a far less important source of primary copper. The oxide copper reserves in the United States are quite small; individual deposits tend to be spotty and smaller in size than the sulfide deposits. In spite of this, the production of copper from oxide sources has recently increased significantly for two basic reasons. The first has been the availability of sulfuric acid in the West as a consequence of air pollution control measures at the copper smelters smelting sulfides. In the absence of nearby outlets for sulfuric acid, the producers have used this acid for leaching available oxide ores, mine dumps containing oxide minerals, mill tailings, etc. In this manner, the producers have tried to dispose of the acid via recovering additional copper. Second, at the same time, the technology of acid leaching and the understanding of the leaching phenomena has increased significantly in recent years. Over the next decade, we believe the acid leaching of oxides will continue to be practiced principally as an acid disposal technique and will not represent an important new source of copper supply. The reserves of oxide copper and the costs of copper extraction are such that the use of discretionary acid (produced from elemental sulfur) for the leaching of oxides will not be economically justified.

Finally, scrap (copper-based and other than copper-based) as noted in Chapter III, is a significant source of copper supply, accounting for over 40 percent of domestic copper consumption; this ratio has remained fairly stable in the past. To recapitulate, there are two types of scrap: new and old. New scrap is that originating in the manufacturing process and is recycled promptly. Old scrap is that recovered from obsolete equipment (e.g., radiators, wires, etc.). Copper obtained from scrap enters the supply stream in two forms: as refined copper, in which case it becomes indistinguishable from primary or mined refined copper, and in the form of scrap, which

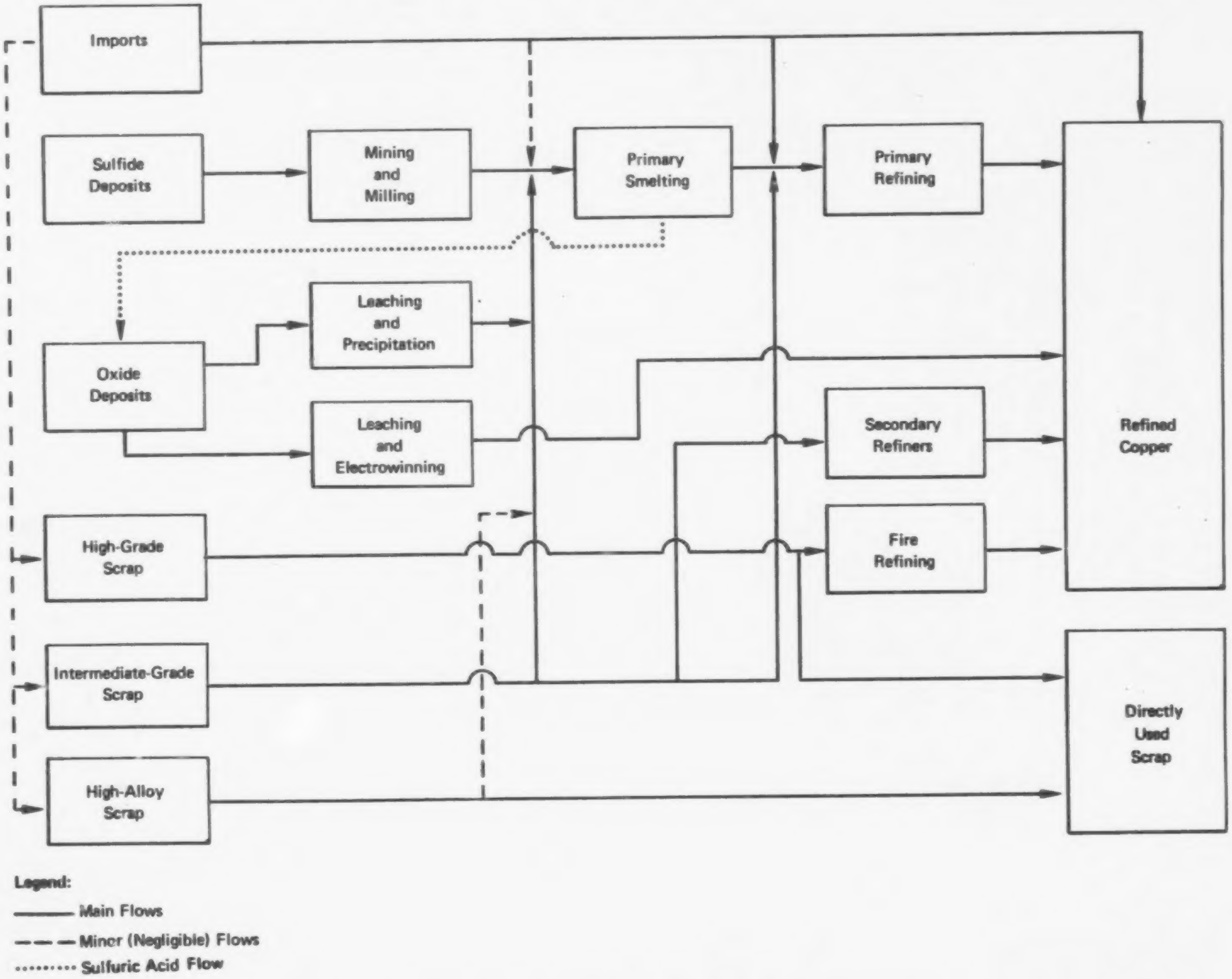

Imports
Sulfide Deposits
Mining and Milling
Primary Smelting
Primary Refining
Leaching and Precipitation
Oxide Deposits
Leaching and Electrowinning
Secondary Refiners
Fire Refining
Refined Copper
High-Grade Scrap
Intermediate-Grade Scrap
High-Alloy Scrap
Directly Used Scrap
Legend:
Main Flows
Minor (Negligible) Flows
Sulfuric Acid Flow

FIGURE VI–1 A SCHEMATIC FLOW DIAGRAM OF MAJOR SOURCES OF COPPER SUPPLY IN THE UNITED STATES

is used directly. The composition of the scrap has a major effect on how it is recycled. High grade scrap can be recycled after only melting and fire refining. Scrap containing precious metals (e.g., electronic machinery and equipment) is usually refined electrolytically, either by the primary or the secondary refiners. High alloy scrap (e.g., brass and bronze) is usually recycled back into the same industry and relatively little of such scrap is refined.

Although the supply of secondary copper is inelastic, it is not completely unresponsive to changes in price. The supply of new scrap is particularly inelastic, whereas the supply of old scrap is less so. If recycling is more broadly defined to include the recycling of the products containing copper (e.g., auto parts, electric motors, etc.), the supply of secondary copper may end up being somewhat more price elastic than generally believed. This proposition, however, has not been put to a rigorous test.

Other potential sources of copper in the future include native copper deposits, such as in Michigan, and ocean nodules.

2. Copper Reserves

As noted in Chapter III, reserves are not static but change over time as a function of prices, exploration activity and technology. Prices, for example, directly affect the stock of reserves, since, all else remaining equal, the lower the grade of ore and the higher the cost of extraction, the higher must be the price for its recovery to be profitable.

To recapitulate, copper reserves in the United States have been estimated at about 90 million short tons of copper (metal content), with an additional 320 million short tons in the form of "other" deposits, including undiscovered (hypothetical and speculative) deposits. The United States accounts for about 20 percent of known world copper reserves and other copper resources. Five states--Arizona, Utah, New Mexico, Montana, and Michigan--account for more than 90 percent of the total domestic reserves. The average ore grade of the domestic reserves held by such major producers as Kennecott, Phelps Dodge, Anaconda, Magma range in the neighborhood of 0.70 - 0.80 percent (refer to Table VI-1); the ore grade of the reserves at some currently producing mines (e.g., Duval-Sierrita, Cyprus-Bagdad, etc.) falls well below this range.

TABLE VI-1

ESTIMATED RESERVES OF MAJOR UNITED STATES COPPER PRODUCERS
(End of 1976, except as otherwise noted)

Company and Mine	Ore Reserves (millions of short tons)	Grade of Copper (%)	Amount of Recoverable Copper (thousands of short tons)
Kennecott Copper Corp.	2,759.0	-	16,200.0[a]
Utah Copper Division	1,573.0	0.71	9,500.0
Chino Mines Division	428.0	0.74	2,300.0
Ray Mines Division	667.0	0.79	3,900.0
Nevada Mines Division	91.0	0.67	500.0
The Anaconda Company[b,d]	2,754.3	-	NA
Butte Mines	1,597.3	-	NA
Berkeley Pit	68.4[c]	1.23	NA
Continental-North	497.6	0.49	NA
Continental-East	29.2	0.40	NA
Kelley	69.0	0.87	NA
Steward (below 2,000 foot level)	97.1	0.67	NA
Steward (additional deposit)	820.0	0.74	NA
Leonard (Minnie Healy Horsetail zone)	16.0	1.90	
Yerrington Mine	1,157.0	-	NA
Ann Mason	495.0	0.40	NA
MacArthur (1)	6.5	0.44	NA
MacArthur (2)	6.5	0.42	NA
Lyon	32.0	1.22	NA
Bear	500.0	0.40	NA
Phelps Dodge Corporation[e]	1,900.0	0.78	11,500.0
Magma Copper Corporation[f]	1,130.0	0.76	7,050.0
Cyprus[g]	300.0	0.49	NA
Duval Corporation[h]	522.0	-	NA
Esperanza	25.8	0.42	NA
Mineral Park	55.5	0.29	NA
Battle Mountain			
Copper Canyon	6.1	0.59	NA
Copper Basin	0.8	1.04	NA
Sierrita	489.6	0.32	NA
ASARCO Incorporated	377.6	-	NA
Mission	141.2	0.73	NA
Sacaton			
Open Pit	24.2	0.70	NA
Underground	16.7	1.23	NA
San Xavier			
Oxide Ore	3.3	1.04	NA
Sulfide Ore	167.4	0.52	NA
Silver Bell	24.8	0.66	NA
White Pine[i]	90.3	1.17	NA
Inspiration Consolidated Copper Company	NA	NA	1,455.9
Inspiration Area Mines	NA	NA	913.0
Christmas Mines			
Underground	NA	NA	283.8
Open Pit	NA	NA	116.2
Sanchez Mine	NA	NA	142.9
Cities Service Company[j]	350.0	0.44	1,250.0

NOTES:

[a] Does not include copper producible through leaching of waste dumps.

[b] Subsidiary of Atlantic Richfield Company. The estimates refer to July 1, 1976 and are obtained from The Anaconda Company, Notice of Special Meeting of Shareholders (September 15, 1976), pp. 64-70.

[c] Excludes an additional, almost continguous, 41.1 million short tons deposit which remains inadequately sampled and the ore grade for which is not known.

[d] Excludes data for Anamax Mining Co., under equal partnership with Amax, Inc.

[e] Phelps Dodge does not give detailed information on its reserves; the ore grade, not available for 1976, refers to 1974.

[f] Wholly-owned subsidiary of Newmont Mining Corporation; the figures refer to 1974.

[g] Includes only the year-end reserves reported for Cyprus Bagdad Copper Company, a wholly-owned subsidiary of Cyprus.

[h] Wholly-owned subsidiary of Pennzoil Company.

[i] Wholly-owned subsidiary of The Copper Range Company; the reserves refer to copper sulphides and native copper ore.

[j] Data refer to 1974.

SOURCES:

Corporate Annual Reports; 10-K forms submitted to Securities and Exchange Commission; Arthur D. Little, Inc., estimates.

3. The Economics of Exhaustible Resources: Copper Supply and Prices in Theoretical Perspective

We present below a review of the main principles and findings of the economics of exhaustible resources in order to provide a perspective in understanding the supply behavior of copper producers.

The fast-growing literature on this subject is traceable to Hotelling's classic 1931 article[1]. In this article, Hotelling presented an extensive study of the economics of exhaustible resources. Using a rigorous mathematical framework, he studied the conditions for the optimal exploitation of a resource and the utilization of the tax structure in controlling the extraction rate of a resource.

Hotelling's article spurred more recent studies, focusing mainly on the economics of renewable resources. The last decade has been particularly productive in the sense that there have been many significant contributions.

According to the fundamental theory of exhaustible resources as originally derived by Hotelling, the scarcity rent of the resource, which is the market price of the resource less extraction costs, would increase at the rate of interest. At the depletion time, the market price must be equal either to the zero demand price (Herfindahl[2]) or the cost of a perfect substitute (Nordhaus[3]), assuming no adjustment costs in switching to the substitute (Hanson[4]). The substitute may be defined in terms of "backstop technology"--to use a phrase given prominence by Nordhaus[3] to describe the case where, if the society is willing to pay the price, significantly higher cost deposits can be tapped to replace the lower cost deposits currently used (e.g., the extraction of oil from shale serves as a backstop against the exhaustion of conventional oil deposits).

The fundamental principle of the economics of exhaustible resources is, as Solow has argued, simultaneously a condition of flow equilibrium in the market for the ore (which Hotelling had in mind) and of asset equilibrium in the market for deposits[5]. Do these flow and asset equilibrium conditions have any explanatory value, for example, with respect to the long-run supply and pricing behavior of the producers? Even though the answers are quite aggregative (or too general) or even unclear, they provide instructive insights.

The flow equilibrium is that the net price (or marginal profit) should be rising exponentially[6], at a rate approximating the rate of social time-preference (i.e., the rate at which society would evaluate trade-offs in consumption between different periods). If the net prices are considered or expected by the producers to be rising too slowly, mine owners will conclude that resource deposits are an inferior way to hold wealth, relative to other assets they could hold, and will pull out. They may do so by increasing current production and convert ore into money. This would drive down copper prices, moving down along the demand curve. If there is an initial disequilibrium (such as there exists currently), this will be worsened to the extent that expectations about future price changes are conditioned by today's events. The market, in other words, is unstable. If, conversely, the producers believe the rate of net price increase exceeds the interest rate and, consequently, withhold supplies from the market, this may lead to a speculative run-up of prices which, like its opposite, is self-reinforcing. In short, initial disequilibrium, however described, becomes magnified, with production tilting either toward excessive current production or toward speculative withholding of supply. However, to the extent that longer-run prospects have some bearing on today's events, the instability just alluded to becomes dampened. Nevertheless, the answer is not clear over the long-run, since many complicating factors may arise affecting the volume of reserves, competition from new materials or the development of new technologies[7].

A further point concerns the optimal rate of exploitation of an exhaustible resource, such as copper. In this respect, ignoring details, Solow finds amusing the conclusion emerging from the theory of extractive resources that a monopolist will exhaust a mine (a resource) more slowly than will a competitive industry facing the same demand schedule. The amusing aspect of this is that if a conservationist is someone who would like to see resources conserved beyond the rate that is possible under a perfectly competitive market, then the monopolist is the conservationist's friend[8]. This is because, in economic theory, a monopolist restricts output to maximize profits, which results in lower output and higher prices than would hold under perfect competition. According to this theory, a monopolist in an extractive industry would maintain higher prices for virgin materials than would otherwise occur in a perfectly competitive market and would thus act as a conservationist, slowing down the depletion of virgin materials and inducing recycling via the umbrella of his higher prices.

This brings up two additional points, the first relating to the exploitation of a resource with a differential quality of deposits (i.e., ore grade differences exist). The other has to do with the supply behavior of the primary producers in the presence of recycling.

Solow and Wan studied the first question through the use of an aggregative model and concluded that it is not optimal to use any high-cost resource until the low-cost resource is exhausted. On the related question of the largest sustainable constant level of consumption, their striking finding is the suggestion that relatively large changes in resource availability generate very small changes in the sustainable level of consumption[9].

On the second question (i.e., the relationship between production from a resource pool and recycling) can be cited an analysis by Gaskins of Alcoa as a monopoly with an inexhaustible supply of mineral deposit facing competition only from recycling[10]. Although not applicable to the copper industry, Gaskins concluded that it would pay the monopolist to limit production and keep prices high initially and then to expand production as recycling increased.

4. Long-Run Supply Behavior in the United States Copper Industry: An Overview

As noted in Chapter IV--Financial Characteristics of the United States Copper Industry and the Principal Companies, given access to ore bodies, investments required in the copper industry are quite sizeable, as this is a rather capital intensive industry. These investments are long-term in nature; a good-sized copper mine and a corresponding mill would be developed not for a few years' production but quite possibly to produce for decades. Investment in a new smelter or refinery would not take place in isolation but would be linked to future mine and mill production expectations. Thus, investments are interrelated in the industry, at different stages of production, both functionally and temporally. Also, in the face of a great deal of uncertainty surrounding copper prices stemming mainly from the industry's cyclicality and the consequent fluctuations in prices, long-term investments in the copper industry are highly risky. Further, ore bodies frequently involve lead, zinc, silver and/or other metals of potential interest in addition to copper. Because of these reasons, the interests of the companies in the nonferrous metals industries are frequently intertwined, in terms of buyer-seller relationships (e.g., smelting/refining services) or joint investments. Joint ventures, which constitute a means of diversification and pooling of risks, have consequently become quite common in the industry.

The scale of investments, the long-term nature of the investments, the element of risk arising from the industry's cyclicality (not to mention competition offered by both the secondary and foreign producers, or the threat of long-run substitution for copper by other materials, and the pooling of risks through joint ventures all suggest that the primary producers have basically a long-term orientation in their pricing and investment decisions. This suggests that their investment decisions, leading over time to the creation of new productive capacity to supply anticipated future consumption levels, are motivated by an expected long-run target rate of return on investment defining their ex ante "incentive price" (i.e., the price at which the firms would find it profitable to stay in business over the long-run, where the revenues are sufficient to cover full costs, including a return on investments high enough to attract new capital).

C. CAPACITY GROWTH TRENDS

This section discusses domestic capacity growth tends in copper industry, with principal emphasis on smelter/refinery capacity growth. Given this study's overall purpose, primary focus is placed on patterns of growth in smelter capacity. The important point to note here is that historically domestic smelter capacity growth has occurred mainly through incremental additions to existing smelter operations, rather than the building of new "grassroots" (or greenfield) smelters, i.e., smelters in new locations.

1. Smelter Capacity Growth Trends

Traditionally, smelters have been situated near the mines in order to minimize transportation charges for concentrates. With the major copper mines centered in the Western states, most of the smelting capacity is in that area. In 1974, out of 18 operational smelters (two of these owned and operated by secondary refiners), 13 were located west of the Mississippi. The 13 western smelters are operated by five of the six integrated companies (Kennecott, Phelps Dodge, Anaconda, Inspiration, and Magma) who mine a major portion of their respective smelter input, and by Asarco, a major portion of whose input comes from ores mined by other companies.

Since 1974, Phelps Dodge has commissioned a new smelter, the Hidalgo smelter in New Mexico, with an annual capacity of about 400,000 to 500,000 tons of material. In addition, two existing smelters, Anaconda and Garfield have undergone substantial process changes.

The capacity of a smelter is normally expressed in terms of the quantity of material treated, assuming a smelter opration rate of 24 hrs/day 350 days/year at full design capacity. This is because the bottlenecks in smelting (materials handling, heat input rate, etc.) place an upper bound on the total quantity of material that can be handled, irrespective of the copper content of this material. Thus, although the quantity of input (feed or charge) materials handled and refined-equivalent smelter output would normally vary linearly, a smelter's output can be increased by increasing the copper content of the material smelted. Alternatively, capacity at an existing smelter can be expanded by the addition of new equipment to eliminate the bottlenecks.

Tables VI-2 and VI-3 show smelter capacity growth trends over the period 1950-1975[11] in terms of the quantity of feed materials. So defined, smelting capacity during the past two and one-half decades has never been as great as it was at the beginning of the 1950s. In spite of an expansion of capacity in the late 1950s and early 1960s, by 1967 capacity had declined to a level only slightly above that existing in 1953. During the following eight yeras total capacity fluctuated sharply, but by 1975 was only 300,000 tons (or 3.5 percent) greater than that existing in 1953. During the same period (i.e., 1953-1975) smelter output of blister copper increased by about 40 percent. This increase was achieved by improved beneification techniques which increased the copper content of concentrates and also because of improvements in reverb smelting technology.

2. Refinery Capacity Growth Trends

The major portion of the smelter output of blister copper is electrorefined. Copper electrolytic refineries have traditionally been located near consumers on the Atlantic Coast. More recently, several refineries have been built in the West and several old East Coast refineries have been shut down. A smaller portion of smelter output is fire refined, principally in New Mexico and Michigan.

The capacity of an electrolytic refinery can be changed by altering operating conditions but there is usually a trade-off involved. For example, capacity can be increased by increasing current density but at the cost of higher energy consumption and higher impurity carry over to the product.

The growth pattern in dometic refinery capacity over the period 1958-1975 is shown in Table VI-4. Overall, refinery capacity expanded by about 38 percent over the 1958-1975 period. Unlike the fluctuating growth trend in smelter capacity, net changes in refinery capacity have been positive with the exception of two years, 1962 and 1972. The figures in Table VI-4 indicate how responsive producers have been to general conditions in the business cycle and the demand cycle for copper, with the bulk of refinery capacity expansion occurring in response to business expansion and rising copper demand over the period 1964-1970.

Prior to 1971, most of the capacity expansion was in the form of additions to existing plants; no new plants were built in the United States during the period 1959-1971. In 1971, however, Magma opened a new 200,000 annual short ton refinery in San Manuel, Arizona. By 1973, three secondary refiners--Chemetco, Reading, and Southwire--had

TABLE VI-2

GROWTH OF UNITED STATES COPPER SMELTING CAPACITY[a] 1950-1975

(short tons of material; end-of-year figures, as reported by American Bureau of Metal Statistics, Inc.)

Year	Smelting Capacity	Change in Smelting Capacity	Change in Smelting Capacity due to new Plants	Change in Smelting Capacity due to Expansion (Contraction) of Existing Plants
1950	9,551,000[b]	-	-	-
1951	9,653,000[b]	102,000	0	102,000[c]
1952	9,653,000[b]	0	0	0
1953	8,318,000	-1,335,000	0	-1,335,000[d]
1954	8,368,000	50,000	0	50,000[e]
1955	8,348,000	-20,000	0	-20,000[f]
1956	8,225,000	-123,000	70,000[g]	-193,000[h]
1957	8,415,000	190,000	0	190,000[i]
1958	8,600,000	185,000[j]	400,000	-215,000[j]
1959	8,600,000	0	0	0
1960	8,600,000	0	0	0
1961	8,700,000	100,000	0	100,000[k]
1962	8,623,000	-77,000	0	-77,000[l]
1963	8,423,000	-200,000	0	-200,000[m]
1964	8,423,000	0	0	0
1965	8,371,000	-52,000	0	-52,000[n]
1966	8,371,000	0	0	0
1967	8,383,000	12,000	0	12,000[o]
1968	9,079,000	696,000	0	696,000[p]
1969	8,689,000	-390,000	0	-390,000[q]
1970	8,704,000	15,000	0	15,000[r]
1971	8,821,000	117,000	0	117,000[s]
1972	8,521,000	-300,000	0	-300,000[t]
1973	8,496,000	- 25,000	0	- 25,000[u]
1974	8,626,000	130,000	0	130,000[v]
1975	8,611,000	- 15,000	0	- 15,000[w]

NOTES:

[a] Excludes producers of Lake Copper.

[b] Includes the capacity of the Phelps Dodge Corporation, United Verde Branch, Clarksdale, Arizona, smelter (1,400,000 short tons of annual capacity) which closed down June, 1950.

[c] Expansion in the capacity of Kennecott Copper Corporation, New Mexico plant at Hurley, New Mexico (from 288,000 to 400,000 short tons), minus the contraction in the capacity of the Kennecott Copper Corporation, Nevada plant at McGill, Nevada (from 450,000 to 440,000 short tons).

[d] Expansion in the capacity of the American Metal Company, Ltd., Carteret, New Jersey smelter (from 200,000 to 265,000 short tons) minus the shutdown of the Phelps Dodge Corporation, United Verde Branch, Clarksdale, Arizona smelter (1,400,000 short tons annual capacity), which closed down June, 1950.

[e] Expansion in the capacity of the American Smelting and Refining Company, El Paso, Texas, smelter (from 300,000 to 350,000 short tons).

[f] Contraction in the capacity of the American Metal Company, Ltd., Carteret, New Jersey, smelter (from 265,000 to 245,000 short tons).

[g] The new San Manuel Copper Corporation, San Manuel, Arizona, smelter, a wholly owned subsidiary of Magma Copper Company.

[h] Expansion in the capacity of the American Smelting and Refining Company, El Paso, Texas, smelter (from 350,000 to 400,000 short tons) minus the contraction in the capacity of the following smelters:

Asarco, Garfield, Utah (from 1,608,000 to 1,440,000 short tons).

Asarco, Tacoma, Washington (from 675,000 to 600,000 short tons).

[i] Expansion in the capacity of the San Manuel Copper Corporation, San Manuel, Arizona, smelter (from 70,000 to 360,000 short tons) minus the contraction in the capacity of the Magma Copper Company, Superior, Arizona, smelter (from 250,000 to 150,000 short tons).

[j] The new Kennecott Copper Corporation, Ray Mines Division, Hayden, Arizona, smelter (400,000 tons annual capacity) minus the contraction in the capacity of the smelting facilities at Garfield, Utah, purchased by Kennecott Copper Corporation from American Smelting and Refining Company (from 1,440,000 to 1,225,000 short tons).

[k] Expansion in the capacity of the following smelters:

Asarco, El Paso, Texas (from 400,000 to 420,000 short tons).

Asarco, Hayden, Arizona (from 300,000 to 360,000 short tons).

Tennessee Copper Company, Copperhill, Tennessee (from 70,000 to 90,000 short tons).

[l] Contraction in the capacity of the American Metal Climax, Inc., Carteret, New Jersey, smelter (from 245,000 to 168,000 short tons).

[m] Shutdown of the Phelps Dodge Refining Corporation, Laurel Hill, New York smelter (200,000 short tons annual capacity).

[n] Expansion in the capacity of the following smelters:

> Asarco, Hayden, Arizona (from 360,000 to 420,000 short tons).
>
> Inspiration Consolidated Copper Company, Miami, Arizona (from 360,000 to 450,000 short tons).
>
> Magma Copper Corporation, San Manuel Division, San Manuel, Arizona (from 360,000 to 403,000 short tons).
>
> Kennecott Copper Corporation, Ray Mines Division, Hayden, Arizona (from 400,000 to 420,000 short tons).
>
> Minus the contraction in the capacity of the following smelters:
>
> Kennecott Copper Corporation, Nevada Mines Division, McGill, Nevada (from 440,000 to 400,000 short tons).
>
> Kennecott Copper Corporation, Utah Mines Division, Garfield, Utah (from 1,225,000 to 1,000,000 short tons).

[o] Expansion in the capacity of the American Metal Climax, Inc., Carteret, New Jersey, smelter (from 168,000 to 180,000 short tons).

[p] Expansion in the capacity of the following smelters:

> Asarco, El Paso, Texas (from 420,000 to 576,000 short tons).
>
> Asarco, Hayden, Arizona (from 420,000 to 960,000 short tons).

[q] Contraction in the capacity of the Phelps Dodge Corporation smelter at Douglas, Arizona (from 1,250,000 to 860,000 short tons).

[r] Expansion in the capacity of the Phelps Dodge Corporation smelter at Douglas, Arizona (from 860,000 to 875,000 short tons).

[s] Expansion in the capacity of the Magma Copper Corporation, San Manuel Division, San Manual, Arizona, smelter (from 403,000 to 670,000 short tons) minus the permanent shutdown of the Magma Copper Corporation, Superior Division, Superior, Arizona, smelter (150,000 short tons annual capacity).

[t] Contraction in the capacity of the Anaconda Company, smelter at Anaconda, Montana (from 1,000,000 short tons to 750,000 short tons) plus contraction in the Phelps Dodge Corporation, New Cornelia Branch, Ajo, Arizona, smelter (from 300,000 short tons to 250,000 short tons).

[u] The new Chemetco, Inc., Alton, Illinois, smelter (150,000 short tons annual capacity) minus the contraction in the Phelps Dodge Corporation smelter at Douglas, Arizona (from 875,000 short tons to 700,000 short tons).

[v] Expansion in the capacity of the Magma Copper Corporation, San Manuel Division, San Manuel, Arizona, smelter (from 670,000 to 800,000 short tons).

[w] Contraction in the capacity of the Cities Service Company, smelter at Copperhill, Tennessee (from 90,000 to 75,000 short tons).

SOURCE: Yearbook of the American Bureau of Metal Statistics, Inc., (ABMS), annual yearbook volumes, 1958-1975.

TABLE VI-3

GROWTH OF LAKE COPPER SMELTING CAPACITY[a] IN THE UNITED STATES, 1950-1975

(short tons of product; end-of-year figures, as reported by American Bureau of Metal Statistics, Inc.)

Year	Smelting Capacity	Change in Smelting Capacity	Change in Smelting Capacity Due To New Plants	Change in Smelting Capacity Due To Expansion (Contraction) of Existing Plants
1950	197,000 [b]	---	---	---
1951	197,000 [b]	0	0	0
1952	112,000	-85,000	0	-85,000 [c]
1953	112,000	0	0	0
1954	92,000	-20,000	0	-20,000 [d]
1955	128,000	36,000	36,000 [e]	0
1956	128,000	0	0	0
1957	137,000	9,000	0	9,000 [f]
1958	157,000	20,000	0	20,000 [g]
1959	162,000	5,000	0	5,000 [h]
1960	167,000	5,000	0	5,000 [i]
1961	177,000	10,000	0	10,000 [j]
1962	177,000	0	0	0
1963	177,000	0	0	0
1964	177,000	0	0	0
1965	177,000	0	0	0
1966	202,000	15,000	0	15,000 [k]
1967	132,000	-70,000	0	-70,000 [l]
1968	132,000	0	0	0
1969	135,000	3,000	0	3,000 [m]
1970	135,000	0	0	0
1971	135,000	0	0	0
1972	105,000	-30,000	0	-30,000 [n]
1973	105,000	0	0	0
1974	105,000	0	0	0
1975	105,000	0	0	0

NOTES:

[a] Includes Lake Superior District producers only.

[b] Capacity figure includes the idle capacity of the Copper Range Company, Smelting Department, Houghton, Michigan (85,000 short tons of product annual capacity).

[c] Shut down of the capacity of the Copper Range Company, Smelting Department, Houghton, Michigan (85,000 short tons of product annual capacity).

[d] Contractions in the capacity of the Calumet and Hecla, Inc., Hubbell, Michigan, smelter (from 100,000 to 80,000 short tons).

[e] The new White Pine Copper Company, White Pine, Michigan, smelter.

[f] Expansion in the capacity of the White Pine Copper Company, White Pine, Michigan, smelter (from 36,000 to 45,000 short tons).

[g] Expansion in the capacity of the Calumet and Hecla, Inc., Hubbell, Michigan, smelter (from 80,000 to 100,000 short tons).

[h] Expansion in the capacity of the White Pine Copper Company, White Pine, Michigan, smelter (from 45,000 to 50,000 short tons).

[i] Expansion in the capacity of the White Pine Copper Company, White Pine, Michigan, smelter (from 50,000 to 55,000 short tons).

[j] Expansion in the capacity of the White Pine Copper Company, White Pine, Michigan, smelter (from 55,000 to 65,000 short tons).

[k] Expansion in the capacity of the White Pine Copper Company, White Pine, Michigan, smelter (from 65,000 to 90,000 short tons).

[l] Contraction in the capacity of the Calumet and Hecla, Inc., Hubbell, Michigan, smelter (from 100,000 to 30,000 short tons).

[m] Expansion in the capacity of the Quincy Mining Company, Hancock, Michigan, smelter (from 12,000 to 15,000 short tons).

[n] Shut down of the capacity of the Universal Oil Products Company, Calumet Division, Hubbell, Michigan, smelter (30,000 short tons annual capacity).

SOURCE: Yearbook of the American Bureau of Metal Statistics, annual volumes, 1958-1975.

TABLE VI-4

COPPER REFINERY EXPANSION IN THE UNITED STATES, 1958-1975

(short ton of product; end-of-year figures, as reported by American Bureau of Metal Statistics, Inc.)

Years	Refinery Capacity	Change in Refinery Capacity	Change in Refinery Capacity due to New Plants	Change in Refinery Capacity due to Expansion (Contraction) of Existing Plants
1958	2,108,500	-	-	-
1959	2,309,000	200,500	198,000[a]	2,500[b]
1960	2,331,500	22,500	0	22,500[c]
1961	2,341,500	10,000	0	10,000[d]
1962	2,334,500	- 7,000	0	7,000[e]
1963	2,334,500	0	0	0
1964	2,364,500	30,000	0	30,000[f]
1965	2,420,500	56,000	0	56,000[g]
1966	2,430,500	10,000	0	10,000[h]
1967	2,522,000	91,500	0	91,500[i]
1968	2,643,000	121,000	0	121,000[j]
1969	2,676,000	33,000	0	33,000[k]
1970	2,676,000[o]	0	0	0
1971	2,793,000[o]	117,000	200,000[l]	-83,000[m]
1972	2,723,000	-70,000	0	-70,000[n]
1973	2,850,000	127,000	132,000[p]	- 5,000[q]
1974	2,850,000	0	0	0
1975	2,909,000	59,000	420,000[r]	-361,000[s]

NOTES:

[a] The new Kennecott Refining Corporation, Anne Arundel County, Maryland, refinery.

[b] Expansion in the capacity of the White Pine Copper Co., White Pine, Michigan, refinery (from 45,000 to 50,000 short tons), minus the contraction in the capacity of the Inspiration Consolidated Copper, Inspiration, Arizona refinery (from 47,500 to 45,000 short tons).

[c] Expansion in the capacity of the Lewin-Mathes Co., Division of Cerro de Pasco Corporation, St. Louis, Maryland, refinery (from 25,000 to 45,000 short tons).

[d] Expansion in the capacity of the White Pine Copper Corporation, White Pine, Michigan, refinery (from 55,000 to 65,000 short tons).

[e] Expansion in the capacity of the American Metal Climax, Inc., Carteret, New Jersey, refinery (from 121,000 to 125,000 short tons) minus the contraction in the capacity of the American Smelting and Refining, Tacoma, Washington, refinery (from 114,000 to 103,000 short tons).

[f] Expansion in the capacity of the Inspiration Consolidated Copper, Inspiration, Arizona refinery (from 45,000 to 65,000 short tons) plus expansion in the capacity of the Phelps Dodge Refining Corporation, El Paso, Texas, refinery (from 290,000 to 300,000 short tons).

[g] Expansion in the capacity of the following refineries:

> The Anaconda Company, Great Falls, Montana (from 150,000 to 180,000 short tons);
>
> Inspiration Consolidated Copper, Inspiration, Arizona (from 65,000 to 70,000 short tons);
>
> Kennecott Copper Corporation, Hurley, New Mexico (from 84,000 to 103,000 short tons);
>
> Phelps Dodge Laurel Hill, Long Island, New York (reactivated, 20,000 annual short tons);

minus the contraction in the capacity of the Kennecott Copper Corporation, Garfield, Utah, refinery (from 204,000 to 186,000 short tons).

[h] Expansion in the capacity of the following refineries:

> The Anaconda Company, Great Falls, Montana (from 180,000 to 190,000 short tons);
>
> White Pine Copper Company, White Pine, Michigan (from 65,000 short tons to 90,000 short tons);

minus the contraction in the capacity of the International Smelting and Refining Company, Raritan, Perth Amboy, New Jersey (from 240,000 to 215,000 short tons).

[i] Expansion in the capacity of the following refineries:

Asarco, Baltimore, Maryland (from 198,000 to 318,000 short tons);

Asarco, Tacoma, Washington (from 103,000 to 108,000 short tons);

Phelps Dodge Refining Corporation, El Paso, Texas (from 300,000 to 320,000 tons);

minus the contraction in the capacity of the following refineries:

Lewin-Mathes Co., Division of Cerro Corporation, St. Louis, Missouri (from 42,500 to 39,000 short tons);

Phelps Dodge Refining Corporation, Laurel Hill, Long Island, New York (from 175,000 to 155,000 short tons);

Calumet and Hecla, Inc., Hubbell, Michigan (from 60,000 to 30,000 short tons).

[j] Expansion in the capacity of the following refineries:

United States Metals Refining Co., Carteret, New Jersey, a subsidiary of American Metal Climax, Inc. (from 150,000 to 175,000 short tons);

Asarco, Tacoma, Washington (from 108,000 to 126,000 short tons);

Kennecott Refining Corporation, Anne Arundel County, Maryland (from 198,000 to 276,000 short tons);

Phelps Dodge Refining Corporation, El Paso, Texas (from 320,000 to 420,000 short tons);

Lewin-Mathes Co., Division of Cerro Corporation, St. Louis, Missouri (from 39,000 to 44,000)

minus the contraction in the capacity of the following refineries:

International Smelting and Refining Co., Raritan, Perth Amboy, New Jersey (from 215,000 to 150,000 short tons);

United States Metals Refining Co., Carteret, New Jersey, a subsidiary of American Metal Climax, Inc. (from 125,000 to 85,000 short tons).

[k] Expansion in the capacity of the Asarco, Tacoma, Washington, refinery (from 126,000 to 156,000 short tons) plus expansion in the capacity of the Quincy Mining Co., Hancock, Michigan, refinery (from 12,000 to 15,000 short tons).

[l] Magma Copper Company, San Manuel, Arizona.

[m] Contraction in the capacity of the Phelps Dodge Refining Corporation, Laurel Hill, Long Island, New York, refinery (from 155,000 to 72,000 short tons).

[n] Contraction in the capacity of the following refineries:

The Anaconda Company, Great Falls, Montana (from 190,000 to 185,000 short tons);

International Smelting and Refining Company, Raritan, Perth Amboy, New Jersey (from 150,000 to 115,000 short tons);

Shutdown of Calumet Division, Universal Oil Products Company, Hubbell, Michigan (annual capacity 30,000 short tons at the end of 1971), which was idle in 1970 and 1971.

[o] Includes the "idle" capacity of the Calumet Division, Universal Oil Products Co., Hubbell, Michigan refinery (30,000 short tons annual capacity).

[p] The following new refineries started operations in 1973:

Chemetco, Inc., Alton, Illinois (40,000 short tons annual capacity);

Reading Industries, Inc., Reading, Pennsylvania (20,000 shorts tons annual capacity ,

Southwire Company, Copper Division, Carrollton, Georgia (72,000 short tons annual capacity).

[q] Contraction in the capacity of The Anaconda Company, Great Falls, Montana, refinery (from 185,000 to 180,000 short tons).

[r] The new Asarco, Amarillo, Texas, refinery.

[s] Expansion in the capacity of the Anaconda Company, Great Falls, Montana, smelter (from 180,000 to 252,000 short tons) minus the shut down of the following smelters:

Anaconda Company, Raritan plant, Perth Amboy, New Jersey (115,000 short tons annual capacity)

Asarco, Baltimore, Maryland (318,000 short tons annual capacity).

SOURCE: Yearbook of the American Bureau of Metal Statistics, annual volumes, 1958-1975.

come on-stream with a total capacity of 132,000 annual short tons. Further, in 1975, Asarco began operations at its new 420,000 annual short ton capacity refinery in Amarillo, Texas; at the same time, however, it shut down operations at its 318,000 annual short ton capacity Baltimore refinery and its 168,000 annual short tons capacity Perth Amboy refinery.

D. TRENDS IN COSTS OF PRODUCTION

The primary producers are faced with two kinds of costs--variable and fixed costs--at each of the four stages of processing of primary metal--mining, milling, smelting, and refining. In some cases, cost categories as viewed by copper industry management may not necessarily reflect the economists' definition of fixed and variable costs; however, the fixed-variable cost distinction will prove important later in our analysis of production costs and shifts in production costs due to compliance with environmental regulations.

Five relevant categories of annual operating costs or variable costs can be identified: materials; energy and fuels; operating supplies; plant maintenance; and part of sales, administration and overhead.

Fixed costs are defined to include the following: general administration costs (some portion); exploration and research costs (as capitalized); interest expense; property taxes and insurance; depreciation; income taxes (adjusted for variations in output); net income (i.e., a desired rate of after-tax return on assets). The first four capital charges are real costs borne by each producer. Costs of depreciation do not represent actual costs; that is, they are not cash charges, but rather are balance sheet items reflecting a cash flow. Net income is treated as a fixed cost by the producers in pricing decisions (i.e., they must receive a return on investment at least equal to the opportunity cost of capital).

1. Past Trends in Primary Producer Costs

Accurate estimation of production costs for copper in the United States is a difficult undertaking, both because of the variations in actual costs facing individual producers and because individual producers do not normally disclose detailed cost-of-production data.

However, there is general agreement that:

- Costs of mining and concentrating have traditionally formed, by far, the largest proportion of total production costs of refined copper. Smelting and refining costs have represented only a small proportion of the total cost, with smelters and refineries functioning mainly as "service" operations on fixed and relatively low profit margins.

TABLE VI-5

INDEX OF OUTPUT PER MAN-HOUR SERIES FOR PRODUCTION OR NONSUPERVISORY WORKERS, SIC 1021 (COPPER MINING AND MILLING), 1963-1975

(1967=1.000)

Year	Average employment (thousands)[a]	Average weekly hours[a]	Total average annual man-hours (millions)	Index of man-hours (1967=1.000)	U.S. domestic mine production of recoverable copper[d] (thousands of short tons)	Output index (1967=100.0)	Index of output per man-hour (1967=1.000)
1963	22.7	43.1	50.875	1.291	1213.166	1.272	0.985
1964	22.1	42.9	49.301	1.251	1246.780	1.307	1.045
1965	24.7	43.4	55.743	1.415	1351.734	1.417	1.001
1966	26.2	43.5	59.264	1.504	1429.152	1.498	0.996
1967	19.1	43.0	39.394[c]	1.000	954.064	1.000	1.000
1968	21.3	47.0	48.053[c]	1.220	1204.621	1.263	1.035
1969	26.9	46.3	64.764	1.644	1544.579	1.619	0.985
1970	29.3	44.7	68.105	1.729	1719.657	1.802	1.042
1971	26.8[b]	42.9	59.785	1.518	1522.183	1.595	1.051
1972	30.7[b]	41.6[b]	66.410	1.686	1664.840	1.745	1.035
1973	33.7[b]	42.3[b]	74.126	1.882	1717.940	1.801	0.957
1974	33.8[b]	41.1[b]	72.237	1.834	1593.590[e]	1.670	0.911
1975	28.4[b]	39.2[b]	57.891	1.470	1410.989[e]	1.479	1.000

NOTES AND SOURCES:

[a] U.S. Department of Labor, Bureau of Labor Statistics (BLS), Employment and Earnings, United States, 1909-72, Bulletin No. 1312-9, pp. 10, 11 (for years 1963-1970 only).

[b] BLS, Employment and Earnings:
1971: Vol. 18, No. 9 (March, 1972), pp. 50, 81.
1972: Vol. 19, No. 9 (March, 1973), pp. 50, 81.
1973: Vol. 20, No. 9 (March, 1974), pp. 54, 85.
1974: Vol. 21, No. 9 (March, 1975), pp. 52, 85.
1975: Vol. 22, No. 9 (March, 1976), pp. 56, 89.

[c] To avoid errors due to prolonged strikes in these two years, total annual average man-hours have been computed on a monthly basis before summing up to obtain the annual total.

[d] Data refer to mine production of recoverable copper (copper content) in the form of blister. Source (1963-1973): Copper Development Association, Inc. (CDA), Copper Supply and Consumption, 1955-1974 (New York: CDA, 1975), pp. 8, 9.

[e] 1974: U.S. Bureau of Mines, Mineral Industry Surveys, Copper in 1974 (April 8, 1975), p. 3. 1975: *Ibid.*, Copper in 1975 (March 26, 1976), p. 3.

[f] The indexes of output per man-hour are computed by dividing the output index by the index of total average annual man-hours.

- Overall, real costs of refined copper production appear to have remained stable or to have increased only gradually during the 1950s and 1960s. There is evidence, however, that real costs have begun to rise sharply in the last few years.

- Labor productivity growth, on the other hand, stagnated through the 1950s and 1960s and productivity has actually registered a slight decline since 1971 in the face of continued degradation of average ore grades being mined in the United States. The industry, in effect, may have come close to exhausting possible productivity gains from existing technology.

Orrice C. Herfindahl in the late 1950s advanced the hypothesis that the long-run price of copper tends to equal the long-run economic cost of copper or the price sufficient to induce continued investment at all stages of production, from exploration to refining[12]. According to Herfindahl's estimates, the long-run economic cost of producing copper in the United States was fairly stable at 25-30 cents per pound between the early 1920s and 1957. Herfindahl argued that copper producers, through technological change, were able to keep pace with real increases in factor costs during this period.

Over the period 1957-1968, as pointed out in a paper, by Raymond Mikesell[13], the deflated average United States producers price for refined copper remained reasonably close to the upper range of Herfindahl's estimated long-run cost of copper. After 1968, however, the average producers price, in real terms, climbed substantially higher.

Productivity growth in the copper industry, meanwhile, has been relatively stagnant since the early 1960s, with productivity gains lagging behind those experienced by other United States industries. Table VI-5 indicates that output per man-hour at the mining and milling stage rose only slightly between 1963 and 1971 and registered a slight absolute decline in the period after 1971.

The combination of a long-term trend towards escalation in the producers' price (in real terms) and stagnant or negative productivity growth suggests that the long-run real economic cost of producing copper has been rising in recent years.

Table VI-6, which shows recent increases in the prices of materials and energy, leads partial support to the general proposition that the cost of copper production has increased in real terms in recent years.

The industry's productivity problem lies in the lack of availability of radically new technologies to take the place of conventional mining practices associated with open-pit mines. The average copper content of the ore mined in the United States declined from about .85 percent in 1957 to .55 percent in 1972[14]. Conventional stripping technology has been unable to offset the increased cost associated with mining lower grade ores.

Several new approaches may be utilized in the future to overcome some of the potential constraints on growth of productivity in the industry. First, newly-developed pit slope engineering techniques may be employed to steepen slopes and thereby decrease stripping ratios, as well as to increase the amount of ore in a given mine which is economically recoverable. In addition, the same design concepts associated with steepening slopes can be utilized for predictable controlled caving of slopes as an alternative to drilling and blasting under some conditions. Finally, the development of self-propelled crushers and belt-conveyors would eliminate the need for use of trucks in hauling ore and overburden.

2. Estimates of Base Year (1974) Primary Producer Costs

As suggested earlier in the chapter, variable costs represents costs incurred for inputs which can be varied in the short-term by changing the firm's output; total variable costs increase as the firm's output increases, since larger output normally requires increased variable inputs (e.g., labor, raw and intermediate goods, energy, etc.). Fixed costs, on the other hand, represent total obligations over a given unit of time (e.g., year) incurred by a firm for fixed capital inputs which are independent of the level of output.

Our estimate of the average variable costs for producing refined copper (over all four stages of production) for the primary producers in 1974 was 43¢ per pound, representing the weighted average of company-specific production cost data for eleven major producers (including both integrated and non-integrated companies).[15]

Our estimate of the average fixed costs for the primary producers (over all four stages of production) for 1974 was about 29¢ per pound. This figure, if anything, errs on the high side, by one or two cents per pound; it was obtained by cross-checking a number of different sources and historically observed average fixed cost data for the primary producers.

TABLE VI-6

WHOLESALE PRICE INDEX SERIES FOR MAJOR COMPONENTS OF OPERATING AND MAINTENANCE COSTS, UNITED STATES COPPER INDUSTRY (SIC 1021-COPPER ORES AND SIC 3331-PRIMARY COPPER), 1963-1975

Years	Materials and components, parts, containers and supplies (excl. energy)[a]		Purchased electric power[c]		Purchased fuels[f]	
	(1967=100.0)	(1974=100.0)[b]	(1967=100.0)	(1974=100.0)[b]	(1967=100.0)	(1974=100.0)[b]
1963	94.3	61.2	101.3	62.1	96.1	52.0
1964	94.8	61.5	100.4	61.6	93.8	50.7
1965	96.3	62.5	100.1	61.4	95.6	51.7
1966	99.1	64.3	99.6	61.1	99.6	53.9
1967	100.0	64.9	100.0	61.3	100.0	54.1
1968	102.6	66.6	100.9	61.9	98.6	53.3
1969	106.3	69.0	101.8	62.4	100.1	54.1
1970	110.2	71.5	104.8	64.3	104.3	56.4
1971	113.8	73.8	113.6	69.7	110.0	59.5
1972	117.9	76.5	121.5	74.5	112.7	61.0
1973	129.2	83.8	129.3	79.3	125.6	67.9
1974	154.1[d]	100.0	163.1[d]	100.0	184.9	100.0
1975[d]	171.1[e]	111.0	176.5[e]	108.2	225.9	122.2

NOTES AND SOURCES:

[a] Wholesale price index (WPI) for total manufactured goods.

[b] The base year is shifted from 1967 to 1974, by dividing the series by the 1974 index.

[c] WPI 054-Electric power.

[d] U.S. Department of Labor, Bureau of Labor Statistics, Monthly Labor Review (January, 1976), various tables.

[e] U.S. Department of Labor, Bureau of Labor Statistics, Wholesale Prices and Price Indexes for January through December; average of data for January through December.

[f] WPI 05 (Fuels and related products and power) minus WPI 054 (Electric power) minus WPI 0561 (Crude petroleum). This measurement provides a broad coverage of various types of fuel used by the copper industry, in mining through refining (i.e., included, among others, are natural gas, distillate, and residual fuels).

We have computed this price index series as follows:

Let $\overline{\Delta}P = \Delta P_1W_1 + \Delta P_2W_2 + \Delta P_3W_3$

where

$\overline{\Delta}P$: change in WPI 05 (Fuels and related products and power) between 1967 (1967 = 100.00) and a given year:

ΔP_1 : change in WPI 054 (Electric power) between 1967 and a given year;

ΔP_2 : change in WPI 0561 (Crude petroleum) between 1967 and a given year;

ΔP_3 : change in "rest of WPI 05" (i.e., WPI 05 minus WPI 054 minus WPI 0561)

W_1, W_2, W_3 : weights in WPI 05 associated with P_1, P_2, and P_3, respectively;

$$\sum_{i=1}^{3} W_i = 1.0$$

We can solve for ΔP_3W_3 as follows:

$$\Delta P_3W_3 = \overline{\Delta}P - \Delta P_1W_1 - \Delta P_2W_2$$

where $\overline{\Delta}P$, ΔP_1 and ΔP_2 can be computed from the following series on $\overline{P}$, P_1 and P_2:

Years	$\overline{P}$	P_1	P_2
1963	96.3	101.3	98.7
1964	93.7	100.4	98.3
1965	95.5	100.1	98.2
1966	97.8	99.6	98.9
1967	100.0	100.0	100.0
1968	98.9	100.9	100.8
1969	100.9	101.8	105.2
1970	105.9	104.8	106.1
1971	114.2	113.6	113.2
1972	118.6	121.5	113.8
1973	134.3	129.3	126.0
1974	208.3	163.1	211.8
1975	245.1	176.5	245.7

SOURCES: 1963-1973: U.S. Department of Labor, Bureau of Labor Statistics, Handbook of Labor Statistics, Table 129;
1974: U.S. Department of Labor, Bureau of Labor Statistics, Wholesale Price Indexes, Supplement 1975 (September, 1975) Table 5;

1975: U.S. Department of Labor, Bureau of Labor Statistics, Wholesale Price Indexes, monthly January through December, 1975, Table 6.

The weights W_1, W_2 and W_3 are computed as follows:

W_1 = 1.728/7.697 = 0.2245

W_2 = 0.635/7.697 = 0.825

W_3 = 1.000 - 0.2245 - 0.825 = 0.6930

where

1.728 is the weight in the total WPI associated with WPI 054 (Electric power);

0.635 is the weight in the total WPI associated with WPI 0561 (Crude petroleum); and,

7.697 is the overall weight in the total WPI associated with WPI 05 (Fuels and related products and power).

SOURCE: U.S. Department of Labor, Bureau of Labor Statistics, Wholesale Prices and Price Indexes, Supplement 1975 (September, 1975), Table 4.

In making the cost estimates, we have assumed constant returns to scale when firms are operating at between roughly 45-86 percent of installed capacity; beyond this region, diminishing returns to scale are assumed to set in. In other words, in the 45-86 percent range, average variable costs are equal to marginal costs; beyond 86 percent of capacity the average variable and marginal cost schedules (functions) not only rise sharply but also, of course, diverge[16].

Where production cost data were not available directly from companies themselves, estimates of average variable costs were made by taking into account differential ore grades, stripping ratios, recovery rates and mining technology. Since smelting and refining processes involve quite standard technologies with known input requirements, the cost differentials observed were generally reflective of different ore grades and mining costs among the different companies.

In summary, average total costs for the primary producers in 1974 were estimated at 72¢ per pound[17]. Costs of new capacity expansion have been estimated at $5,000 per annual short ton (in constant 1974 dollars), $1,600 per annual short ton of smelting and refining capacity and $3,400 per annual short ton of mining and milling capacity.

E. THE QUANTITATIVE ANALYSIS OF SUPPLY BEHAVIOR IN THE COPPER INDUSTRY

The quantitative analysis of supply behavior in the copper industry attempts to explain the short-run and long-run supply response of the copper producers by considering such variables as prices, production costs, capital costs, ore grade and reserves, among others. The approach typically taken in the past in modeling the supply response of mineral/resource industries is that of the "supply curve" approach. This is the approach taken in virtually all modeling work performed in the past (for example, by Charles River Associates, Inc.--CRA). This section presents a critical review of the supply curve (supply function) approach to modeling the supply behavior of copper producers and indicates broadly how we approached this problem in this study. The thrust of our comments is directed to the use or applicability of the supply curve approach in modeling the supply behavior of the primary producers.

1. The Supply Curve for Primary Copper

The concept of the supply curve is a tool of partial equilibrium analysis in economics. Neglecting the analytical complications that would arise from the presence of secondary, as well as foreign, suppliers, the basic supply function for primary copper can be expressed as $Q = f(P)$, where Q and P are the quantity and price vectors, respectively, given the state of technology, factor prices, and the reserve situation. An important related concept in analyzing the supply response of the primary copper producers is the price elasticity of supply, which is a measure of the responsiveness of supply to price, expressed as a ratio of the percentage change in quantity associated with a given percentage change in price. In continuous terms it is expressed in terms of the following formula:

$$\gamma_s = \frac{P}{Q} \cdot \frac{\delta Q}{\delta P} .$$

A distinction needs to be drawn between the short-run and long-run supply curve. The short-run supply curve shows the relationship between price and output with a given level of capacity, where productive capacity represents the binding constraint. Because of the capacity constraint, the producers have limited scope for expanding their production as prices rise.

The long-run supply curve shows the relationship between price and output, when there are no constraints on productive capacity (i.e., by definition, over the long-run, all factors of production are perfectly mobile). If the supply curve slopes upward gently, the price elasticity of primary copper supply will be high; consequently, small percentage increases in price will lead to large percentage increases in the quantities offered. If, however, the curve is steeply sloped, the elasticity will be low; in such a situation, even large price increases will not bring forth large quantities of primary copper onto the market.

2. Criticisms of the Supply Curve Approach

The supply function (curve) approach to modeling the supply response of firms in a mineral/resource industry, such as the primary copper industry, suffers from serious deficiencies. First, the supply function approach has little, if any, microeconomic theoretical validity in imperfectly competitive (e.g., oligopolistic) markets. Second, the short-run and long-run distinction in specifying and estimating supply functions fails to cope with the dynamics of the adjustment process between the short-run and the long-run, via capacity expansion. Indeed, the process of capacity expansion, as part of an evolving reality, is completely ignored in the supply function approach. Third, the estimation of supply functions through the use of econometric techniques is fraught with serious practical and theoretical difficulties.

a. Microeconomic Theoretical Criticisms

The concept of the industry supply curve has validity only under conditions of perfectly competitive markets. Another way of saying the same thing is that a supply function does not exist under conditions of imperfect competition in the product markets.

"Perfect competition" is characterized by:

- a very large number of firms (buyers and sellers) where each firm accounts for an extremely small share of the market;
- a homogenous or standardized product is involved;
- the numerous buyers and sellers are well-informed about product quality and about each other's prices;
- the entry of new firms into the industry/market is free and easy (i.e., there are no "barriers to entry").

Under these conditions, individual firms have no influence over the going market price; each firm is a "price taker" and decides only how much to produce and sell, under prevailing prices, given its cost structure. Each firm acts atomistically, that is, it decides its level of output ignoring the others in the industry. Since the products of the firms are perfect substitutes for one another the price-elasticity of demand facing the individual firm is infinite (i.e., the demand function facing the firm is horizontal).

In the short-run, given the market price level, the profit maximizing position for the firm is to produce that quantity at which price equals marginal cost, moving along its marginal cost schedule which defines its supply curve. At the industry level, this equilibrium condition is obtained at the intersection of the industry supply and demand curves, where the industry supply curve is obtained by horizontal summation of the marginal cost curves of the producing firms. For an industry characterized as perfectly competitive, a unique, deterministic equilibrium solution for prices and quantities is thus obtained at the intersection of the supply and demand curves. These short-run conditions do not, in general, apply to firms under imperfect competition. Deterministic market solutions, based upon the supply and demand functions alone, are no longer possible and, in the general case (e.g., in an oligopolistic market), a range of possible price and output solutions can be expected on purely theoretical grounds.

The concept of a long-run supply function for an imperfectly competitive industry rests on equally shaky ground. It will be recalled that for an industry under perfect competition, the long-run supply function--where supply is defined to include both actual and potential firms--will be horizontal at the break-even point, assuming constant factor prices, and will be sloping upward if the industry's expansion puts upward pressure on its factor prices. The break-even point defines the long-run equilibrium price at which the unit cost (average total cost) is at the lowest point permitted by factor prices and technical knowledge. At long-run equilibrium, when price equals average cost, firms just cover their full competitive costs (i.e., the firms operate at a point of minimum unit cost, corresponding to an optimal scale of operations, with no excess profit). Each firm is forced to operate at this point, under the pressure of competitive conditions. One of these conditions, ensuring such an outcome, is free entry and exit (i.e., no barriers stand in the way).

When entry is blocked (e.g., because of absolute cost differences between the established firms and potential entrants, etc.), market price depends on the behavior of firms already in the industry and, unless individual firms in the industry possess long-run average cost functions that are constant, the result of their expansion would differ from that predicted by long-run equilibrium conditions of perfect competition. That is, if individual firm costs are not constant, the existing number of firms may not produce at the lowest possible cost for the industry, because the firms are not at optimal sizes where average cost in each case is minimal. Under such conditions, excess profits, at least for some firms, may exist on more than just a temporary basis. If there are a few firms, they might not expand; instead, they might reach a tacit understanding to maintain a smaller output at a higher price. In the extreme, they may act as a monopolist. In short, the concept of a long-run industry supply function for an imperfectly competitive industry lacks the theoretical rationale underlying it under conditions of perfect competition; hence, its use under imperfectly competitive conditions to explain the long-run pricing behavior or supply response (expansion) of the firms rests on questionable theoretical foundations.

Apart from these theoretical objections, there are basic empirical issues associated with the use of a short-run or long-run industry supply function in imperfectly competitive markets. These issues arise more generally in econometric practice, but it is helpful to discuss them more specifically in connection with the specification and estimation of industry supply (cost) functions.

b. Dynamics of the Supply Adjustment Process and the Supply Function Approach[18]

The supply adjustment process is typically modeled by taking a "partial adjustment" approach. It is assumed that suppliers can make only a partial adjustment in each period to a change in the current price, and that the change in the actual quantity supplied is equal to some fraction, λ, of the difference between the desired quantity in the given period, t, and the actual quantity in the previous period, t-1. We may, therefore, express the partial adjustment hypothesis with respect to the supply of copper as follows:

$$(1) \quad S_t - S_{t-1} = \lambda(S^*_t - S_{t-1})$$

where $0<\lambda<1$ and where S_t^*, desired quantity in the given period t, is explained as a function of own-price in period t.

$$(2) \quad S_t^* = a + b\,P_t$$

Substituting (2) into (1) we derive

$$(3) \quad S_t = \lambda a + \lambda b\,P_t + (1-\lambda)S_{t-1}$$

These equations state that the actual quantity offered at time t is not the desired quantity, S_t^*, corresponding to the price at time t, but that the adjustment from the quantity in the previous period, S_{t-1}, is some proportion, λ, of the difference between the desired quantity, S_t^*, and the actual quantity in the previous period, S_{t-1}. Likewise, in the previous period, S_{t-1} is not the desired quantity at P_{t-1}, but reflects a partial adjustment from the period $t-2$. Repeated substitution of S for previous periods in Equation (3) would lead to a geometrically distributed lag. Under this hypothesis S_t becomes a function of all past prices, where the effects of each is less the further back we go in time. We may express this process mathematically by the following equation:

$$(4) \quad S_t = a + \lambda b \sum_{i=0}^{\infty} (1-\lambda)^i P_{t-i}$$

For the purpose of econometric estimation, the basic supply equation (for copper) can be written as follows:

$$(5) \quad S_t = \alpha_0 + \alpha_1 P_t + \alpha_2\,S_{t-1}$$

The partial adjustment approach to estimating long-run supply provides a basis for estimating long-run elasticity of supply with respect to changes in prices. Short-run elasticity measures the response of supply to a change in price during a short period, t, say, a year. However, a long-run elasticity is the response of the quantity supplied to a change in price after adjustments in capacity permit a change in actual quantity supplied, S_t, to the desired quantity supplied, S_t^*. In the copper industry it will require a number of years to achieve the desired quantity corresponding to a change in the price of copper in a particular year. The relationship between long-run and short-run elasticity of supply is determined by the coefficient, λ, which measures the proportion of the difference between the desired quantity, S_t^*, and the actual quantity supplied in the preceding period, S_{t-1}. If there were no technical constraints in adjusting supply from year-to-year toward the desired supply, λ would equal 1 and the long-run and short-run elasticities of supply would be the same. Actually, however, supply adjustments will be relatively small each year and full adjustments to the desired supply will take many years.

The relationship between short-run elasticity of supply, e_{SR}, and the long-run elasticity of supply, e_{LR}, may be expressed as:

$$\lambda e_{LR} = e_{SR}$$

Since λ will usually be substantially less than 1, e_{LR} should be some multiple of e_{SR}, or the long-run elasticity of supply of copper should be substantially higher than the short-run elasticity.

The partial adjustment approach to the long-run supply of copper summarized above provides the conceptual approach for modeling supply under conditions of lagged adjustment of the desired quantity corresponding to the market price (or to the expected price under the adaptive expectations hypothesis). However, it has serious weaknesses as a theory of supply.

An adequate long-run supply theory must explain the relationship between the cost and profitability conditions and expectations determining investment decisions, given a wide variety of incentives, opportunities and contraints. Each stage in the process by which copper production capacity is created, from additional exploration to the construction of a mine or a smelter involves investment decisions that take into account a host of variables, among which long-run price expectations are only one. A change in price or price expectation does not set in motion a series of adjustments that lead inexorably to a change in capacity coming on stream ten or more years hence. New orebodies are continually being discovered or prove to be commercially feasible; technology, capital and operating costs, and sources of financing are continually changing and plans can be altered or investments delayed at every stage in the process as new information becomes available. Further, the effects of new environmental regulations affecting copper exploration and development and new capacity creation could not be addressed by the supply function approach, whether or not one attempts to capture the supply adjustment process through a "partial adjustment" type supply function specification and estimation.

c. Econometric Issues and Criticisms

A number of technical econometric difficulties typically arise when estimating supply or production functions from time-series or cross-section data. These principally include the aggregation bias, the simultaneity bias (i.e., the identification problem), and specification bias.

Aggregation bias is hard to avoid and difficult to assess. If, for example, the analyst has a number of observations for a given firm at time t, structural parameters in the cost, supply or production function (given corrections for simultaneity biases) can be estimated. However, when observations come from a cross-section or time series, with pooled data for many firms, the estimated parameters will be biased, unless they are all equal in reality. The degree of bias can be estimated by examining the covariances of the actual micro parameters and the estimated coefficients of auxiliary regressions[19]. However, it is difficult to deal with aggregation problems through this method. Instead, it is advisable to seek to estimate parameters under conditions where they may, indeed, be similar. Thus, sensible aggregation might be possible, in the case of copper, only over time periods characterized by similar economic and technological factors.

Next, simultaneity bias raises particularly difficult technical issues. To judge from the small amount of evidence available[20], single equation estimates in the simultaneous systems will generate important inconsistencies in the parameter estimates. Of course, the reduced form cost function is designed to avoid such difficulties. It must be kept in mind, however, that this will be true only in some cases, but not in all.

The problem of specification errors confronts every econometric analysis. Difficulties particular to cost, supply or production function estimation include the exclusion of managerial ability and other difficult-to-measure inputs[21]. Some analysts approach this problem through analysis of the residuals[22]. It is not clear, however, that this approach provides a successful resolution for the problem.

In the same vein, we should point out that the limitations of econometrically estimating industry supply functions are well documented in recent literature on the economics of the petroleum industry. Various researchers have applied econometric methods to market data for the purpose of inferring the historical relationships between price and the quantity of petroleum produced within an area[23]. A basic limitation of the econometric approach is the inability to control for the influence of resource depletion. The depletion effect operates both on production from existing reserves and on the attempt to augment the reserve stock via exploration. Attempts have been made to identify and account for this phenomenon using aggregative market data, but they have not proven successful. Estimated supply functions have not remained stable for reasonable periods of time and their forecasting performance does not meet a very high standard[24].

3. Approach Adopted in this Study

We have raised above some of the key issues and criticisms associated with the use of the supply function approach in modeling the supply side of the copper market. These points apply particularly to modeling the supply behavior of the primary producers. In dealing with the secondary copper industry segments, we, too, have estimated and used supply functions, since these secondary market segments can be characterized as a "competitive fringe".

The supply behavior of the primary producers has been modeled by taking an integrated approach which simultaneously considers market conditions, capital expenditures for capacity expansion, production costs, and the financial performance of the firms in the industry. This represents an attempt to capture the dynamics of the supply adjustment process for the domestic primary producers.

Briefly, in our analysis, engineering cost functions, as opposed to econometrically estimated cost functions, were used, but only after a careful and comprehensive review of the literature on statistical analysis of cost functions and following some exploratory empirical attempts in this direction. For example, a number of very powerful, generalized models of the production/cost duality were investigated, particularly the trans-log version.

Our exploratory attempts at an econometric analysis of cost functions facing the primary producers was unsuccessful, for a variety of reasons, quite apart from the theoretical issues raised above on industry supply functions and the unavoidable data problems. First, estimation becomes more complicated under assumptions of imperfect competition. Second, the analysis dictated by the econometric approach is essentially long-run, whereas evolving short-run (annual) cost functions are required for the model. Third, the structure of the primary sector embraces four major stages of production (mining, milling, smelting and refining), such that there exist differences in the cost functions of the individual firms horizontally at least at the mining/milling stage and hence differences in cost functions vertically over all four stages of production. This would be difficult to build into an econometric approach. Further, transfer price data on materials flows between stages of production are insufficient to permit production analysis for each stage of production separately. For these reasons it was felt that econometric analysis of cost functions would prove insufficient in the present analysis.

As a result, it was decided that the theoretical rigor of a Cobb-Douglas, CES, or trans-log formulation would have to be sacrificed for the greater realism of engineering and financial cost estimates. This approach was expected to provide not only greater realism but also increased flexibility in dealing with several stages of production and with the differences in the costs of production among firms. The engineering estimates of average variable costs, financially-based estimates of total and average fixed costs (and, consequently the estimation of average total costs) realistically and accurately represent costs of production as perceived and acted upon by the producers.

For our purposes, we have assumed constant returns to scale in the roughly 45-86 percent range of installed capacity, with diminishing returns to scale beyond this region. The implication of this is a linear total cost function until about 86 percent of capacity which becomes nonlinear beyond this point. Consequently, the average variable cost function = marginal cost function is horizontal until about 86 percent of capacity, rising monotonically thereafter and rather steeply near full capacity.

The technical aspects of our approach are summarized in Chapter XI and are explained in detail in the Technical Appendix to this report, entitled Econometric Simulation and Impact Analysis Model of the U.S. Copper Industry.

CHAPTER VI

NOTES

1. Harold Hotelling, "The Economics of Exhaustible Resources", *Journal of Political Economy*", Vol. 39 (April, 1931), pp. 137-175.

2. O. C. Herfindahl, "Depletion and Economic Theory", in M. Gaffney (Ed.), *Extractive Resources and Taxation* (Madison, Wisconsin: The University of Wisconsin Press, 1967).

3. William D. Nordhaus, "The Allocation of Energy Resources", *Brookings Papers on Economic Activity*, 3 (1973), pp. 529-576.

4. See Donald A. Hanson, "Second Best Pricing Policies for an Exhaustible Resource", *The American Economic Review*, Vol. 67, No. 1 (February, 1977), pp. 351-354.

5. Robert M. Solow, "The Economics of Resources or the Resources of Economics", Richard T. Ely Lecture, *The American Economic Review*, Vol. LXIV, No. 2 (May, 1974), pp. 1-14.

6. *Ibid*., p. 6.

7. For some of these points, see *Ibid*., p. 7.

8. *Ibid*.

9. Robert M. Solow and Frederic Y. Wan, "Extraction Costs in the Theory of Exhaustible Resources", *The Bell Jounral of Economics* (Autumn, 1976), pp. 359-370.

10. Darius W. Gaskins, Jr., "Alcoa Revisited: The Welfare Implications of a Secondhand Market", *Journal of Economic Theory*, Vol. 7 (March, 1974), pp. 254-271.

11. Growth in smelting capacity of Lake Superior District producers of Lake copper are broken out in Table VI-3 because capacity figures are reported in tons of product rather than tons of charge material.

12. Orris C. Herfindahl, *Copper Costs and Prices: 1870-1957*, published for Resource for the Future (Baltimore: The Johns Hopkins Press, 1959).

13. Raymond F. Mikesell, "A Note on Orris Herfindahl's Hypotheses Regarding the Long-Run Price of Copper from the Vantage Point of 1975", unpublished draft paper, (November 7, 1975).

14. Ibid.

15. Based on production cost data for Kennecott, Phelps Dodge, Newmont, Duval, Cyprus Bagdad, Amax, Asarco, Copper Range, Inspiration, Cities Service and Anaconda. The data refer to production costs before credits for by-products (e.g., gold, silver, molybdenum; credits for gold in 1974 have been estimated at about 2.5¢/lb.; total credits in 1974 for all three major by-product metals have been estimated at about 4¢/lb.).

    This approach would tend to slightly overstate the average variable costs facing the primary producers in 1974. However, it does make an implicit allowance for ore grade degradation over time. Also as a basis for econometric simulation of future market and investment activity in the industry, the exclusion of by-product credits avoids the assumptions that in the future (a) the prices or production of the by-product metals will remain constant at their 1974 levels (which is not really a desirable assumption) or that (b) the prices of the by-product metals will grow at certain rates (which would introduce new and unnecessary complications and sources of error in the analysis).

16. Refer to the Technical Appendix for more detail.

17. Corresponds to the minimum point on the industry's average total cost (ATC) function, at roughly 86 percent of installed productive capacity.

18. The discussion presented here draws upon Raymond Mikesell, "The Quantitative Analysis of Supply", draft version of Chapter VII in a forthcoming book on the world copper industry.

19. See Henri Theil, Principles of Econometrics (New York: John Wiley and Sons, Inc., 1971), pp. 556-573. Also see A. A. Walters, "Production and Cost Functions: An Econometric Survey", Econometrica, Vol. 31 (January-April), pp. 10-11.

20. J. Marschak and W. H. Andrews, "Random Simultaneous Equations and the Theory of Production", Econometrica, Vol. 12 (July-October, 1944), pp. 143-205; A. A. Walters, "Some Notes on the Cobb-Douglas Production Function", Metroeconomica, Vol. 13 (1961), pp. 121-128.

21. See Zvi Griliches, "Specification Bias in Estimates of Production Functions", Journal of Farm Economics, Vol. 39 (1957), pp. 8-20.

22. Marschak and Andrews, op. cit.

NOTES
(Continued)

23. E. W. Erickson and R. M. Spann, "Supply Price in a Regulated Industry: The Case of Natural Gas". *The Bell Journal of Economics and Management Science*, Vol. 2, No. 1 (Spring, 1971). F. M. Fisher, *Supply and Cost in the U. S. Petroleum Industry: Two Econometric Studies* (Baltimore: The Johns Hopkins Press, 1974). J. D. Khazzoom, "The F.P.C. Staff's Econometric Model of Natural Gas Supply in the United States", *The Bell Journal of Economics and Management Sciences*, Vol. 2, No. 1 (Spring 1971). P. W. MacAvoy, and R. S. Pindyck, *The Economics of the Natural Gas Shortage* (1960-1980), (Amsterdam: North Holland, 1975).

24. See P. L. Eckbo, H. D. Jacoby, and J. L. Smith, "Oil Supply Forecasting: A Disaggregated Process Approach", M.I.T. World Oil Project, Working Paper No. MIT-EL-77-001WP (February, 1977).

VII. DEMAND

A. INTRODUCTION

The discussion in Chapter VI concentrated on the characteristics of copper supply. In this chapter, the focus is on patterns of copper consumption and the dynamics of demand for copper. We first review copper consumption trends and patterns in the past, with emphasis on the following points: (a) key attributes of copper, (b) comparative copper consumption trends in the United States and the world, (c) consumption of refined and nonrefined (scrap) copper, (d) major direct users of copper, (e) consumption of copper by end-use industries, (f) the consumption and uses of copper versus the demand for copper, and (g) definition of the market for copper for demand analysis. Next, we discuss some of the basic theoretical considerations in demand analysis for copper, touching upon such topics as specification and functional forms, long-run substitution in demand, short-run and long-run adjustments in demand, and potential problem areas in econometric estimation. Finally, we review a number of econometric studies of the copper industry in recent years and examine their findings on short-run and long-run demand elasticities, along with our own findings based on our econometric analyses of demand as part of the modeling effort reported in detail in the Technical Appendix to this volume.

Analysis of demand for copper should start with the simple proposition that demand as an economic concept refers to the quantities the buyers are willing to purchase at different prices, everything else being equal. Further, typically, demand analysis represents the quantification of a functional relationship between the quantity of copper demanded and the key factors simultaneously affecting it, including, principally, copper prices, macroeconomic variables influencing the activity levels of semifabricators and end-use industries, and prices of other products (e.g., aluminum) which are substitutable for copper. Demand hence expresses a multivariate relationship which can be quantitatively estimated by using appropriate methods.

Available econometric studies of demand for copper, including our own, generally indicate that in the short-run demand is quite inelastic with respect to both price and activity variables. The long-run elasticity estimates are all greater than the short-run estimates, indicating that the response of demand to relative prices and activity is more sensitive in the long-run. However, even the long-run estimates in about half of the studies examined fall in the inelastic range.

The presence of long-run substitution in demand for copper is generally recognized as an important aspect of demand analysis for copper. In our own econometric work, we have focused the analysis of copper substitutes on aluminum because of its overriding importance as a competitor to copper not only in the past but also potentially in the future.

Appendices B and C given at the end of this volume accompany this chapter. Appendix B presents a review of trends in long-run substitution away from copper, concentrating primarily on aluminum. Appendix C provides tabulations on interindustrial relationships of copper.

B. PATTERNS OF COPPER CONSUMPTION

1. Key Attributes of Copper

Copper is a metal of key importance, both because of its highly desirable properties and because of its diversity of uses. Properties of copper having major significance are its high electrical and thermal conductivity, corrosion resistance, ductility and malleability, durability, low melting point and high strength. In addition, copper has a pleasing color, is nonmagnetic, and is easily finished by plating or lacquering; it can be welded, brazed, and soldered. Because it can be alloyed readily with many other metals to improve certain basic properties, the commercial brasses, bronzes, copper-nickel alloys, and nickel silvers have been developed. Copper has a wide range of uses in today's modern industrial economy, in pure or alloyed form, including such diverse products as plumbing fixtures, ship propellers, electrical wire and car radiators. While aluminum and other materials are substitutable for copper and alloys in many electrical, structural and decorative applications, in still many other uses copper is the preferred and largely nonsubstitutable resource.

2. Copper Consumption in the United States and the World: Comparative Trends

Table VII-1 shows comparative United States and world trends in refined copper consumption over the 1963-1974 period. As indicated here, world consumption of refined copper was about 8.3 million metric tons in 1974. Of this, United States consumption accounted for nearly 2.0 million metric tons or 23.5 percent. The United States share of world consumption of refined copper dropped from 28.8 percent in 1963 to 23.5 percent in 1974, reflecting a relatively higher growth in demand for copper in the rest of the world. Accordingly, while refined copper consumption in the United States has increased by only 1.90 percent per

TABLE VII-1

UNITED STATES AND WORLD COMPARATIVE TRENDS IN REFINED COPPER CONSUMPTION, 1963-1974

(thousand metric tons)[a]

Years	U.S.	World	U.S. as percent of World
1963	1590.0	5519.3	28.8
1964	1690.0	5995.4	28.2
1965	1845.6	6193.2	29.8
1966	2157.8	6444.8	33.5
1967	1797.5	6194.8	29.0
1968	1701.4	6523.3	26.1
1969	1944.3	7148.0	27.2
1970	1854.3	7283.4	25.5
1971	1830.5	7309.9	25.0
1972	2028.6	7944.5	25.5
1973	2218.6	8791.6	25.2
1974	1956.4	8325.4	23.5
Average Annual Compound Growth Rate (Percent)			
1963-1973	3.39	4.77	-
1964-1974	1.47	3.34	-

NOTES: [a] One metric ton (1,000 kilograms) equals 1.102311 short tons (907.185 kilograms = 2000 pounds avoirdupois, where one pound avoirdupose equals 0.453592 kilogram or 453.5924 grams).

SOURCE: Metallgesellschaft Aktiengesellschaft, Metal Statistics 1963-1974 and 1964-1974, pp. 32-33.

year during the 1963-1974 period (1.47 percent/year over 1965-1974 and 3.39 percent/year over 1963-1973), world consumption has recorded a substantially higher rate of growth at 3.81 percent per year over the sample period (3.34 percent/year over 1964-1974 and 4.77 percent/year over 1963-1973).

3. Consumption of Refined and Nonrefined (Scrap) Copper

Copper consumption trends in the United States since 1950 are shown in Table VII-2. It can be seen that refined copper accounts for a large and increasing share of total United States consumption during this period, with directly consumed scrap reaching to over 30 percent by 1974. It should be noted, however, that during this same period the share of refined copper from scrap at smelters and refiners in total refined copper production has increased from 14.3 percent in 1950 to 22.6 percent in 1974. Consequently, refined copper production from scrap plus directly consumed scrap, taken together, account for a larger share of total consumption (i.e., 46.1 percent in 1974).

During the post-war period, United States copper consumption, despite long-term substitution principally from aluminum, shows an upward trend. Over the 1950-1974 period, the growth in total consumption has been relatively slow at 1.31 percent per year. However, since the early 1960's, the growth rate has been significantly higher (4.04 percent/year over 1960-1973 and 2.91 percent/year over 1960-1974).

The data presented in Table VII-2 can be augmented and brought up to date (to 1976), based on information available from United States Bureau of Mines, as follows:

Year	United States Refined Copper Consumption (thousands of short tons)	Percent Change (%)
1973	2,437.0	-
1974	2,194.2	- 9.96
1975	1,534.5	-30.07
1976	1,960.1	27.74

SOURCE: United States Bureau of Mines, Mineral Industry Surveys Copper in 1974 and Copper in December, 1976.

4. Major Direct Users of Copper

As shown in Figure VII-1, there are six major groups of direct users of refined copper and scrap: four copper semifabricating industries--wire mills, brass mills, foundries, and powder mills; ingot makers; and a group of "other" industries such as chemicals, steel, and aluminum.

TABLE VII-2

CONSUMPTION OF COPPER IN THE UNITED STATES, 1950-1974
(copper content, in thousands of short tons)

Year	Total	Refined Copper[b]	Scrap	Percent Composition (%) Total	Percent Composition (%) Refined Copper[b]	Percent Composition (%) Scrap[c]
1950	2272.2	1482.2	790.0	100.0	65.2	34.8
1955	2418.7	1536.7	882.0	100.0	63.5	36.5
1960	2079.3	1372.3	707.0	100.0	66.0	34.0
1965	2995.4	2034.4	961.0	100.0	67.9	32.1
1970	2930.5	2044.0	886.5	100.0	69.7	30.3
1971	2956.0	2017.8	938.2	100.0	68.3	31.7
1972	3266.2	2236.2	1030.0	100.0	68.5	31.5
1973	3481.7	2445.6	1036.1	100.0	70.2	29.8
1974[a]	3106.2	2156.6	949.6	100.0	69.4	30.6
(Average annual compound growth rate)						
1950-1970	1.28	1.62	0.58	-	-	-
1950-1974	1.31	1.57	0.77	-	-	-
1960-1973	4.04	4.54	2.98	-	-	-
1960-1974	2.91	3.28	2.13	-	-	-

NOTES: [a] Preliminary.

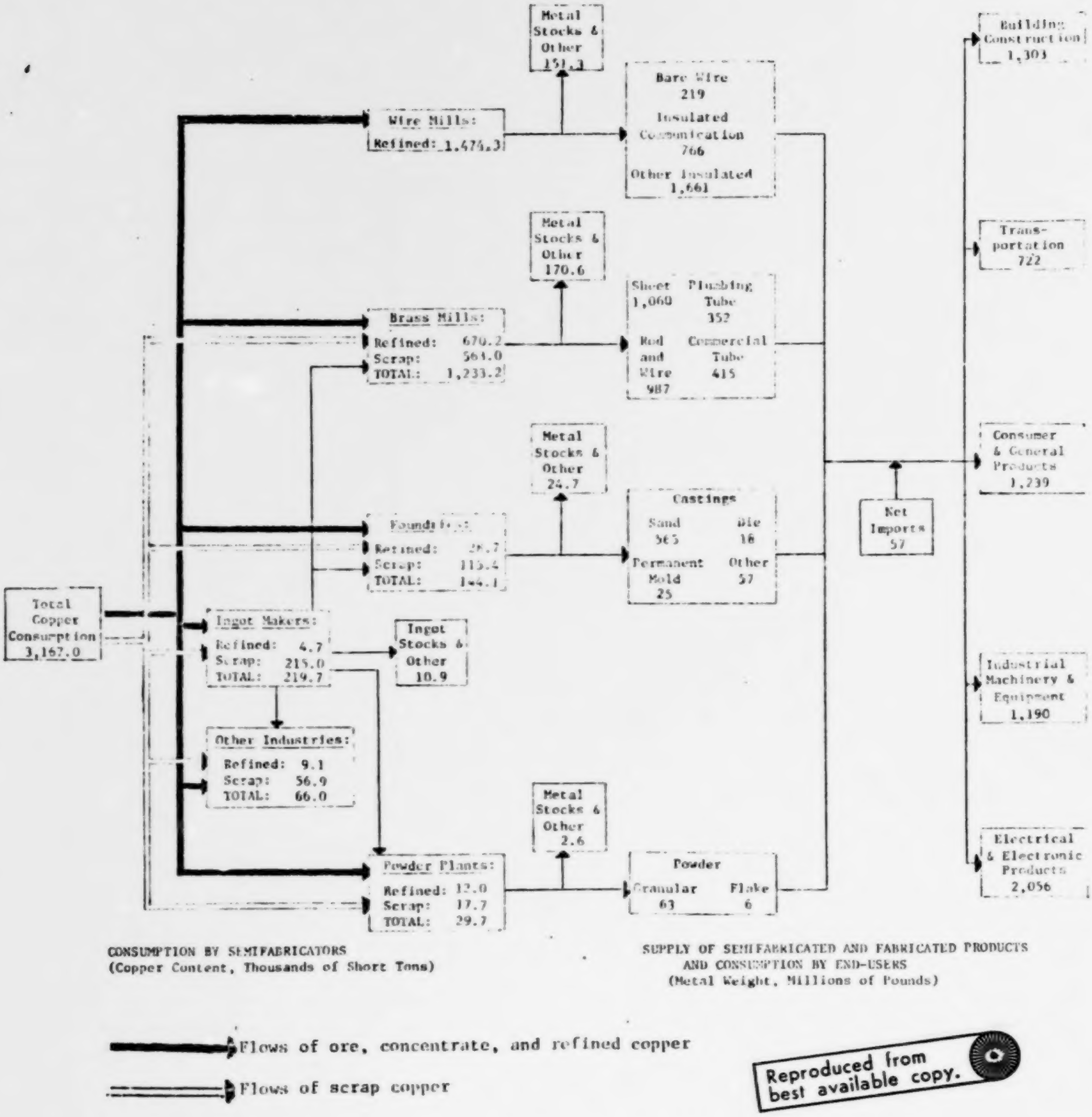
[b] Includes copper refined from scrap.

[c] Refers to directly consumed scrap.

SOURCE: Copper Development Association, Copper Supply and Consumption 1950-1969; 1955-1974.

FIGURE VII-1

COPPER CONSUMPTION IN THE UNITED STATES, 1974
(see below for units)


Total Copper Consumption 3,167.0
Wire Mills: Refined: 1,474.3
Metal Stocks & Other 151.3
Bare Wire 219
Insulated Communication 766
Other Insulated 1,661
Brass Mills: Refined: 670.2 Scrap: 563.0 TOTAL: 1,233.2
Metal Stocks & Other 170.6
Sheet 1,060
Plumbing Tube 352
Rod and Wire 987
Commercial Tube 415
Foundries: Refined: 28.7 Scrap: 115.4 TOTAL: 144.1
Metal Stocks & Other 24.7
Castings
Sand 565
Die 16
Permanent Mold 25
Other 57
Ingot Makers: Refined: 4.7 Scrap: 215.0 TOTAL: 219.7
Ingot Stocks & Other 10.9
Other Industries: Refined: 9.1 Scrap: 56.9 TOTAL: 66.0
Powder Plants: Refined: 12.0 Scrap: 17.7 TOTAL: 29.7
Metal Stocks & Other 2.6
Powder
Granular 63
Flake 6
Net Imports 57
Building Construction 1,303
Transportation 722
Consumer & General Products 1,239
Industrial Machinery & Equipment 1,190
Electrical & Electronic Products 2,056
CONSUMPTION BY SEMIFABRICATORS
(Copper Content, Thousands of Short Tons)
SUPPLY OF SEMIFABRICATED AND FABRICATED PRODUCTS AND CONSUMPTION BY END-USERS
(Metal Weight, Millions of Pounds)
Flows of ore, concentrate, and refined copper
Flows of scrap copper

Reproduced from best available copy.

SOURCE: Arthur D. Little, Inc., based in part on Copper Development Association, Copper Supply and Consumption: 1955-1974. Figures presented here may differ somewhat from those given in Table 7-3.

Ingot makers are, in effect, intermediate processors of refined copper and scrap, producing copper alloy ingot, the bulk of which they sell to the other semifabricating industries, principally brass mills and foundries. While ingot makers and "other industries" are not copper semifabricators as commonly defined, for convenience we shall refer to the aggregate demand schedule of the six consuming groups as the demand for refined copper and its equivalent on the part of semifabricators.

The one characteristic shared by the four semifabricating industries is their use of copper as a basic input. The general task of the semifabricating industries is to alter the shape of copper inputs into products for final end-use. Their production technologies are almost completely different, and their products are not substitutes or complements in any important way. Wire mills, brass mills, and powder mills use mechanical means, while foundries use casting means. Ingot makers produce copper alloy ingot which is then sold to brass mills, foundries, powder plants, and other industries using copper.

Wire mills and brass mills have traditionally been the largest consumers of refined copper and its equivalent accounting for about 86 percent of total consumption in 1974 (refer to Table VII-3). Wire mills, which use only refined copper, consumed about 47 percent, while brass mills, which use refined copper and scrap in fairly equal proportions, consumed about 39 percent. Ingot makers, who almost entirely use scrap, were the third largest consumers at seven percent.

Foundries, which use mostly scrap, consumed about four percent of the total, with powder plants and "other industries" accounting for the remainder.

Over the last two decades, brass mills have generally accounted for 39-42 percent of total consumption; wire mills, on the other hand, have gradually increased their proportion of total consumption from 37 percent in 1956 to the above-mentioned 47 percent. The proportion of total consumption attributable to ingot makers and foundries has declined somewhat over the last two decades.

Table VII-4 provides a breakdown of the various semifabricated products of the four semifabricating industries and gives production levels for 1966, 1970, and 1974 in terms of metal content. Although total output appears to have declined by 10 percent between 1966 and 1974, fluctuations in intervening years not shown make it difficult to discern any secular declining trend. Production of wire mills products increased in absolute terms and as a percentage of the total. Powder mill output remained fairly stable in both absolute and percentage terms, while total production of brass mills products and foundry products declined. Brass and wire mill products account for approximately 85 percent of total production by metal weight for the entire period.

TABLE VII-3

CONSUMPTION OF COPPER PRODUCTS BY DOMESTIC SEMIFABRICATORS, 1974[a]

(thousands of short tons of copper content)

	Refined Copper[b]	Scrap[c]	Total	Percent Breakdown (%)
Wire Mills	1,433.4	-	1,433.4	46.1
Brass Mills	670.3	563.0	1,233.3	39.7
Foundries	28.7	115.4	144.1	4.6
Powder Mills	12.0	17.7	29.7	1.0
Ingot Makers	4.7	215.0	219.7	7.1
Other	7.5	38.5	46.0	1.5
Total	2,156.6	949.6	3,106.2	100.0

NOTES: [a] Preliminary.

[b] Includes refined copper from scrap.

[c] Old and new scrap which is directly consumed.

SOURCE: Copper Development Association, Copper Supply and Consumption, Annual Data, 1955-1974.

TABLE VII-4

PRODUCTION OF SEMIFABRICATED COPPER PRODUCTS, 1966, 1970, 1974

(Thousands of Short Tons)

	1966		1970		1974[a]	
	Metal Content	Percent of Total	Metal Content	Percent of Total	Metal Content	Percent of Total
Wire Mill Products						
Bare Wire	134.5	3.9	113.0	4.0	109.5	3.5
Insulated Communication	323.0	9.4	350.0	12.4	383.0	12.4
Other Insulated	789.5	22.9	701.5	24.9	830.5	26.8
Total	1,247.0	36.2	1,164.5	41.3	1,323.0	42.7
Brass Mill Products						
Sheet	656.5	19.0	441.5	15.7	530.0	17.1
Rod and Mechanical Wire	521.0	15.1	402.0	14.3	493.5	15.9
Plumbing Tube	236.5	6.9	189.0	6.7	176.0	5.7
Commercial Tube	249.0	7.2	224.0	7.9	207.5	6.7
Total	1,663.0	48.2	1,256.5	44.6	1,407.0	45.4
Foundry Products						
Sand Castings	428.0	12.4	310.0	11.0	282.5	9.1
Permanent Mold	23.0	0.7	24.5	.9	12.5	.4
Die Castings	15.0	0.4	11.0	.4	9.0	.3
Other	37.0	1.1	30.0	1.0	28.5	.9
Total	503.0	14.6	375.5	13.3	332.5	10.7
Powder Products						
Granular	30.0		21.5	.7	31.5	1.0
Flake	3.5		2.0	.1	3.0	.1
Total	33.5	1.0	23.5	.8	34.5	1.1
Grand Total	3,446.5	100.0	2,820.0	100.0	3,097.0	100.0

NOTES: [a]Preliminary.

SOURCE: Copper Development Association, Copper Supply and Consumption, 1955-1974.

The right side of Figure VII-1 illustrates the fact that semifabricating industries demand refined copper and its equivalent not for final consumption, but as intermediate inputs in the production of semifabricated products. The demand for semifabricated products on the part of fabricators or end-use industries is, in turn, a derived demand, derived from the demand for final goods being produced by fabricators or end-use industries.

While we focus, in the remainder of this chapter, on patterns of consumption by end-use industries and on methodological approaches to demand analysis, it is important to keep in mind the important role played by end-use industry demand for semifabricated products which determine semifabricators' demand for refined copper and scrap.

5. Consumption of Copper by End-Use Industries

Table VII-5 presents data on consumption of copper by end-use industries. The end-use (fabricating) industrial categories that predominate in the consumption of semifabricated copper are the following in order of importance:

- Electrical and electronics products;
- Building construction;
- Consumer and general products;
- Industrial machinery and equipment;
- Transportation;
- Ordnance and accessories.

The electrical and electronics products industry group has grown to be the principal consumer of copper, accounting for somewhat less than one-third of all annual copper consumption. Building construction continues to be a significant consumer of copper for electrical wiring and pipe. The consumer products industry group grew significantly during the late 1960's; however, its use of copper declined after 1969. While economic conditions may explain part of this decline, substitution and product redesign may also have contributed to this change. The industrial machinery and equipment industry and the transportation industry increased their consumption of copper through 1966; however, by 1970, both industries returned to consumption levels found in 1960.

TABLE VII-5

UNITED STATES COPPER CONSUMPTION BY BROAD END-USE CATEGORIES, 1960-1974
(thousands of short tons)

	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974[a]
Building Construction	478.5	539.5	623.0	648.0	750.5	779.5	780.0	647.5	637.5	711.0	632.0	696.0	749.5	820.5	626.5
Transportation	293.5	297.0	338.5	352.0	398.0	429.5	452.0	351.0	400.5	414.0	333.5	379.0	411.0	459.0	380.0
Consumer and General Products	342.5	358.5	384.0	397.5	469.0	513.5	741.0	752.5	812.5	784.5	601.5	587.0	664.0	702.0	604.0
Electrical and Electronics Products	619.5	604.5	627.0	673.5	752.5	818.0	947.5	797.0	795.0	899.5	835.0	853.5	979.0	1,118.5	1,017.5
Industrial Machinery and Equipment	452.0	446.5	484.0	506.0	556.0	569.5	634.5	519.0	543.0	529.5	484.0	479.5	554.5	586.0	501.0
TOTAL	2,186.3	2,246.0	2,456.5	2,577.0	2,926.0	3,110.0	3,555.0	3,067.0	3,188.5	3,338.5	2,820.0	2,910.0	3,240.0	3,596.0	3,097.0

PERCENTAGE COMPOSITION

	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974[a]
Building Construction	21.9	24.0	25.4	25.1	25.6	25.1	21.9	21.1	20.0	21.3	21.9	23.2	22.3	22.3	20.0
Transportation	13.4	13.2	13.8	13.7	13.6	13.8	12.7	11.4	12.5	12.4	11.6	12.7	12.2	12.5	12.1
Consumer and General Products	15.7	16.0	15.6	15.4	16.0	16.5	20.8	24.5	25.5	23.5	20.8	19.6	19.8	19.1	19.3
Electrical and Electronics Products	28.3	26.9	25.5	26.1	25.7	26.3	26.6	26.0	25.0	26.9	28.9	28.5	29.2	30.3	32.5
Industrial Machinery and Equipment	20.7	19.9	19.7	19.7	19.1	18.3	18.0	16.9	17.0	15.9	16.8	16.0	16.5	15.8	16.1
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

NOTES: [a]Preliminary.

SOURCE: 1969-1974: Copper Development Association, Copper Supply and Consumption, 1955-1974; 1960-1968: Charles River Assocates, Inc. (CRA), Economic Analysis of the Copper Industry (March, 1970), p. 12.

6. Consumption and Uses of Copper Versus Demand for Copper

Analysis of demand for copper requires a distinction between the consumption and uses of copper and the demand for copper. First, the consumption and uses of copper are not definitionally identical. Similarly, uses of copper and the demand for copper differ conceptually. Of these three terms, "consumption" is the most straightforward. Next, while "uses of copper" refers to the disposition of copper on hand, "demand" is an economic concept which refers to the quantities the buyers are willing to purchase at different prices, everything else being equal. The problem typically encountered in demand analysis is to move from consumption data to a data base that more accurately approximates actual market conditions under which, at prevailing prices, producers are willing to supply a certain amount and the consumers are willing to purchase a certain amount (i.e., the market is cleared; supply and demand are equal at the prevailing price level).

Data on copper flows are usually collected in terms of production, consumption, and inventories. Therefore, "demand" (i.e., point estimates of demand over time) must be estimated from these figures, by adjusting either overall production or consumption figures for changes in inventories and/or net exports. How this is precisely accomplished depends on one's analytical objectives. From a theoretical point of view, the choice of approach might be important, but for the objectives of this study, this becomes relatively inconsequential.

On the demand side, the principal use categories for refined copper and refined copper equivalent (e.g., unrefined scrap or copper alloy ingot) are:

- consumption by semifabricators;
- net additions to inventories;
- net exports

The category of net inventory additions can be further subdivided into: (a) stock changes of primary refiners; (b) stock changes of secondary refiners; (c) changes in Federal Government stockpiles, and (d) stock changes of semifabricators.

Table VII-6 indicates the relative importance of alternative uses of refined copper or refined copper equivalent in the United States for selected years from 1954 through 1974[1,2]. Clearly, consumption by semifabricators dominate among uses of refined copper equivalent. Inventory changes at the semifabricator level have represented only a marginal proportion of total uses. Although in some years net exports and changes in primary producer inventories and government stockpiles have represented a somewhat larger proportion of total uses, their net impact on total quantities has been relatively small.

By definition, the total amount of copper supplied by the primary producers, secondary refiners, and scrap suppliers in any year must equal total uses of copper for that year. The "materials balancing" identity or accounting equation can then be represented as follows:

$$QPR + QSR + QSNR = QC + NE + \Delta IGOV + \Delta IF + \Delta IRR + \Delta IRS \qquad (1)$$

where QPR represents the quantity of primary refined copper produced, QSR is the quantity of secondary refined copper produced from scrap, and QSNR represents the quantity of unrefined scrap supplied (and used directly); QC is consumption by semifabricators; NE is net exports, ΔIGOV is the change in government stockpiles; ΔIF is the change in semifabricator inventories; ΔIRR represents the change in inventories of primary refiners; and ΔIRS is the change in inventories of secondary refiners.

If demand is defined as the demand on the part of the domestic semifabricators (definition 1), the relevant figure (QD) can be derived from the consumption side as follows:

$$QD = QC + \Delta IF \qquad (2)$$

Demand could also be defined, more broadly, to include net exports and changes in government inventories (definition 2):

$$QD^* = QC + \Delta IF + NE + \Delta IGOV \qquad (3)$$

These two additional components, when positive, clearly represent additional demand for domestic supplies of refined copper equivalent.

The net result of adjusting semifabricator consumption figures for net exports and government stockpile changes, as well as semifabricators inventory changes, will be as follows: $QD^* > QD$ in years when net exports and government stockpile changes are positive and $QD > QD^*$ when net exports and government inventory changes are negative.

Because we are concerned principally with the dynamics of demand on the part of domestic semifabricators, we have chosen to focus directly on the demand for refined copper equivalent on the part of domestic semifabricators. Aggregate demand figures for the domestic semifabricators industries under definition 1 are presented in Table VII-6.

TABLE VII-6

UNITED STATES SEMIFABRICATOR DEMAND FOR REFINED COPPER AND SCRAP, 1954-1974

(Thousands of Short Tons of Cu Content)

	QC	+	ΔIF	=	QD
1954	1,916.5		-26.0		1,890.5
1955	2,418.7		24.0		2,442.7
1956	2,365.0		7.0		2,372.0
1957	2,106.4		- 2.0		2,104.4
1958	1,974.6		4.0		1,978.6
1959	2,318.6		-39.0		2,279.6
1960	2,079.3		8.0		2,087.3
1961	2,170.0		4.0		2,174.0
1962	2,361.1		5.0		2,366.1
1963	2,565.7		- 8.0		2,557.7
1964	2,775.0		10.0		2,785.0
1965	2,995.4		9.0		3,004.4
1966	3,368.6		63.0		3,431.6
1967	2,850.4		-49.0		2,801.4
1968	2,813.5		-14.0		2,799.5
1969	3,164.2		10.0		3,174.2
1970	2,930.5		64.0		2,994.5
1971	2,956.0		-13.0		2,943.0
1972	3,266.2		-62.0		3,204.2
1973	3,481.7		0.0		3,481.7
1974[a]	3,106.2		75.0		3,181.2

NOTES: [a] Preliminary.

SOURCE: Copper Development Association, Copper Supply and Consumption, 1954-1973 and 1955-1974.

It should be noted, in this connection, that in our construction of a simultaneous-equation econometric model of the copper industry, described in greater detail in the Technical Appendix to this volume, the demand side was given considerably greater attention than may be implied by the above remarks. Specifically, separate equations have been constructed for the various types of inventory holders and for net exports, while changes in government inventory stocks enter the model exogenously.

7. Definition of the Market for Copper for Demand Analysis

Before proceeding with a discussion of the main theoretical issues and econometric approaches in analyzing demand for copper, we should note that, for purposes of analyzing market demand, it is generally accurate to think in terms of a unified market for refined copper, copper scrap, and copper alloy ingot.

As pointed out earlier in this chapter, except for wire mills, semifabricators and fabricators use not only refined copper but also various types of scrap and copper alloy ingot in their operations. Typically the difference between refined copper prices and prices of various types of scrap and copper alloy ingot would be roughly indicative of the added costs to the user of substituting the latter form of copper for the former. Since there are buyers for all possible combinations of products, arbitrage can be fully effective, especially since copper merchants stand ready to trade in virtually all types of copper.

C. DEMAND FOR COPPER: THEORETICAL CONSIDERATIONS

1. Basic Considerations

There are a number of points that deserve emphasis in a discussion of the demand for copper. First, in accordance with economic theory, demand for copper is negatively correlated with its price. That is, if the relationship between the total quantity demanded and the unit price for copper (assuming other variables are held constant) can be stated:

$$Q = F(P)$$

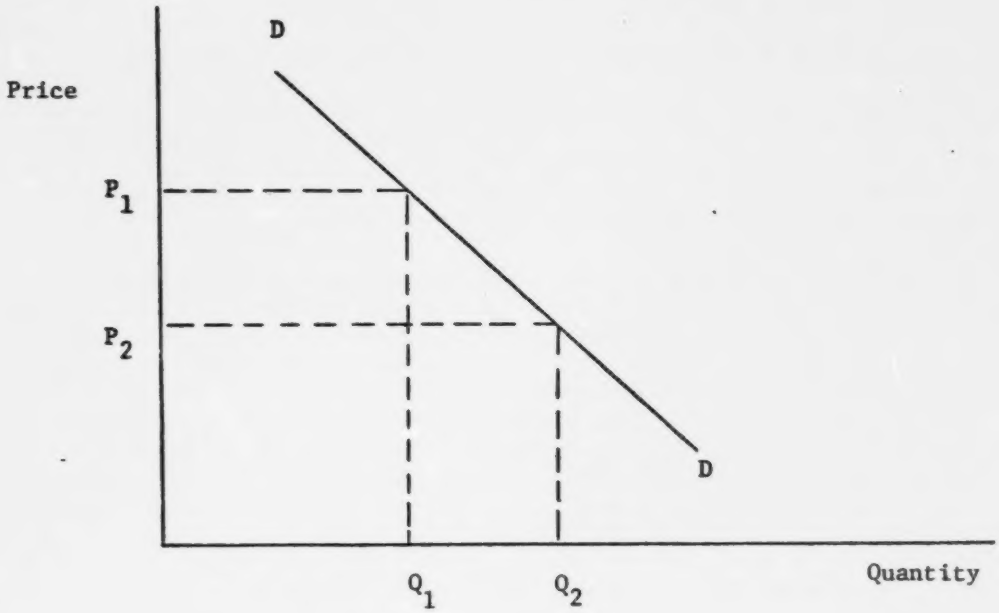
or linearly as

$$Q = \alpha_0 + \alpha_1 P$$

the coefficient α_1 has a negative sign. This equation can be represented graphically by a demand curve (schedule), which indicates the total quantity of copper that would be demanded by a group of users (in this case domestic semifabricators) at various price levels. Thus, the demand curve in Figure VII-2 indicates that, if everything else is

FIGURE VII-2

GENERAL DEMAND SCHEDULE FOR COPPER



held constant and the price of copper (refined copper and its equivalent) is P_1, demand for copper would be Q_1 units. If the price were to fall to P_2, Q_2 would be demanded. Here, the other factors affecting the quantity demanded are held constant in order to isolate the relationship between price and quantity.

Second, the demand for copper is a "derived" demand, which arises from the final demand for the goods for which it is an input. The four semifabricating industries (i.e., brass mills, wire mills, foundries, and powder plants) plus other industries (i.e., chemical, steel, aluminum and other industries) which directly use refined or scrap copper as inputs, buy copper not for purposes of final consumption but for use in their own intermediate production. Their output of semifabricated products is, in turn, demanded by fabricators and end-use industries as intermediate inputs in the production of final durable goods for domestic consumption (i.e., personal consumption or government purchases), investment (i.e., as producers' durable equipment or construction), or exports to the rest of the world. Consequently, we should expect a causal relationship between the general utilization of copper and industrial production of durable manufactured goods, including construction materials. As industrial production of durable manufactured goods increases, the demand for copper would then decrease. If greater specificity in demand analysis is sought, demand for copper can be analyzed by relating it to the activity of the individual end-use industries. This could provide a more differentiated examination of the dynamics of demand, as the share of copper's cost in the total is different for different final products (e.g., in an automobile or a refrigerator its share is very small, whereas in power transmission lines its share is very large).

Third, the demand for copper is positively correlated with the price of substitute goods. For various products which use copper, there are other materials which could be used even though they are not, in general, perfect substitutes for copper in the manufacturing process. The most important substitutes for copper in various uses include aluminum, stainless steel, zinc and plastics. Each substitute is a competitor to copper in limited situations. For example, aluminum is a substitute for copper mainly in wire products, given its high electrical conductivity. For consumer products, plastics are the more important substitutes.

Substitution of aluminum or another material for copper can occur in either the short-run or the long-run. Short-run substitution for copper can take place whenever an alternative material can be used without requiring major alterations in fixed plant and equipment, or changes in product design. The major instances of this sort of substitutions are probably to be found in residential and nonresidential construction. For example, the leading substitutes for copper drainage pipe are plastic and cast iron pipe. Copper pipe is preferred on technical grounds, but if the price becomes too high or copper is simply unavailable, contractors can readily use plastic or cast iron. Decisions on what sort of pipe to use are made frequently, so substitution can take place in the short-run in the sense that it requires no investment and that the effects of a change in price probably occur rapidly.

Short-run substitution can also take place through variations in the copper content of alloy semifabricated products. That is, a consumer who normally uses semis of pure copper or alloys with a very high copper content might switch to alloys with a lower copper content when prices are high. There are also many ways in which the quantity of copper used per unit of output can be reduced.

While it appears that there can occur, in some instances, a noticeable short-run response to changes in price, in many other situations, the capital fixity of plant and equipment will limit the possibilities for substitution in the short-run. While copper and its substitutes may exhibit the same required physical properties in use, the capital in place in the using industry cannot generally be used in processing the substitutes.

Finally, we should comment briefly on the role of speculative demand in demand analysis for copper. Although speculative demand and speculators are often blamed for much of the copper market's instability, it is difficult to tell, to paraphrase Sir Ronald Prain, whether the speculators are the cause or the beneficiaries. While they may influence prices for a very short time, there has yet to be found any way to alter the fundamental laws of supply and demand in the long-run[3].

2. Specification and Functional Forms

Based on the basic points outlined above, the demand for refined copper and its equivalent can be said to be a function of macroeconomic activity levels (driving the activity levels of the end-user industries), the price of refined copper, and the price of substitute products. In an econometric analysis of demand for copper, these would serve as the independent variables. Other factors, such as the prices of complementary commodities and factors of production, probably have some influence on quantities of refined copper demanded, but there is little *a priori* evidence to suggest a degree of influence substantial enough to require their inclusion as explanatory variables in an analysis of demand for copper.

For the most part, the economic theory behind these variables acting as demand determinants is straightforward. As economic activity and income increase, greater quantities of producers' durable goods and consumer durables using copper inputs will be demanded; this will, in turn, lead to a greater derived demand for copper on the part of semifabricators. Similarly, as copper prices increase, semifabricators and end-users will react by cutting back their consumption in most instances. When prices decrease, in most instances semifabricators and end-users will demand more.

Accordingly, a demand equation for copper can be specified showing the relationship not only between the quantity (of copper) demanded and its own price, as given above, but also between the quantity demanded and all of the pertinent variables simultaneously, as shown below:

$$Q = F(P, P^s, Y) \tag{5}$$

This equation simply indicates that although the price of copper (P) affects the quantity demanded (Q), the quantity demanded is also a function of the prices of substitute commodities (P^s), and the income or activity levels (Y) of the users.

The demand curve suggested by Equation (5) is not only static (i.e., time invariant) but also quite general; it indicates only that the variables are causally related in some way to quantities demanded.

In order to introduce greater specificity into the demand equation, it is necessary to look at the production function for semifabricators. This production function is simply a technical relationship indicating the maximum amount of output which can be produced by a producer or industry with each and every set of possible factor inputs (capital, labor, materials). The exact mathematical form of the demand schedule for refined copper equivalent, because it is a derived demand, will reflect the relationship expressed in the aggregate production function for semifabricators[4].

Even given the need to reflect the production function for semifabricators, however, the exact form of the equation can still be specified in different ways, each of which involves different assumptions concerning price and income response behavior of semifabricators (and, by implication, fabricators and end-users) over time. For example, the demand equation introduced above could be specified in linear or nonlinear forms.

The linear form of Equation (5) can be written as follows:

$$Q_t = \alpha_0 + \alpha_1 P_t + \alpha_2 P_t^S + \alpha_3 Y_t + u_t \qquad (5a)$$

where t refers to a given year, α_0, α_1, α_2, α_3 refer to econometrically estimated parameters (coefficients) and u_t is a stochastic (random) disturbance term. The requirements for u_t are that it be independent of the other explanatory variables, be free of autocorrelation and have constant variance.

The general demand curve in Equation (5a) could be utilized to model the demand for refined copper equivalent for each semifabricating industry (wire mills, brass mills, foundries, powder mills, ingot makers, and other industries) separately or for the group of all semifabricating industries consuming refined copper equivalent. Since a derived demand curve reflects the characteristics of the production function of the consuming industry, a demand curve estimated for the aggregation of the semifabricating industries would reflect an amalgamation of each of the production functions of these industries. If the objective is to estimate the parameters of the individual production functions, such an aggregation would probably generate aggregation errors[5]. However, in order to examine the relationship between aggregate demand for copper and price and activity variables, such a disaggregation is not necessary. Furthermore, attempts in the literature to disaggregate demand analysis to individual semifabricating industries have not proved successful[6].

Equation (5) can also take a nonlinear form, such as

$$Q_t = \alpha_0 P_t^{\alpha_1} P_t^{S\alpha_2} Y_t, \qquad (6)$$

which is normally transformed for estimation purposes into the following log-linear (log-log) form:[7]

$$\log Q_t = \log \alpha_0 + \alpha_1 \log P_t + \alpha_2 \log P_t^S + \alpha_3 \log Y_t + u_t. \qquad (6a)$$

The linear form requires the assumption that, whatever the initial price level, an absolute increase in price of a certain amount will lead to an absolute decline in the quantity demanded. Thus, a \$1.00 increase in price will lower the quantity demanded by the same absolute amount whether the initial price is \$10.00 or \$100.00.

The log-log form, on the other hand, imposes the assumption that a proportional (percent) increase in price from any initial price level will lead to a corresponding proportional (percent) decrease in quantity demanded. Consequently, in the log-log specification, a $1.00 price increase from a $100.00 price level (i.e., one percent) would have a much smaller absolute impact on the quantity demanded than a $1.00 increase from a $10 price level (i.e., ten percent).

If a log-log form is used, and the equation is estimated on an annual basis, the nature of the log-log form will cause the estimated price and income elasticities to be constant annually over the entire sample period. This imposed constancy of the elasticity estimates can be undesirable if it is felt that in reality price elasticities change from year to year, given changes in such factors as taste and market conditions. The linear form requires no such assumption, and permits the estimation of differing elasticities as they may change from year to year.

In short, any model of demand applied to a body of data imposes certain inherent constraints. If the range of price variation has historically been small, the assumption of a fixed absolute quantity response to an absolute price change (as in the linear form) may not be worrisome. In fact, in such a case, the ability of the linear formulation to estimate differing elasticities over the sample period may be analytically helpful.

3. Long-Run Substitution in Demand

Long-run substitution (LRS) has been a serious concern on the part of the copper industry, especially since 1947 when the price of copper went above the price of aluminum for the first time. Although the relative price of copper has fallen sharply on occasion in the past (e.g., during 1957 and again during the last half of 1970), the upward trend was resumed shortly thereafter.

Industry observers are not in complete accord on the importance of LRS. However, it is generally agreed that aluminum has been the most serious competitor to copper, having made the most serious inroads in electrical conductor and heat-exchanger applications.

The most important potential instances of LRS are in telephone conductor cable and automobile radiators. Conductor cable and automotive radiators account for roughly 25-30 percent of total demand for primary copper in the United States. There is also clearly LRS in the demand for copper electric transmission cable where aluminum has almost completely displaced copper for overhead transmission and the possibility of LRS in the demand for several other markets has been mentioned in the trade press. In general, LRS is present in most of the markets for copper wire, and these constitute 60 percent of the demand for refined copper. More detailed information on LRS in specific cases in provided in Appendix B.

Substitution for copper will occur only when the relative price of a substitute for copper becomes low enough to justify engineering and tooling costs required to alter the capital equipment of the using sector. The full substitution from copper to a competing commodity will occur only in the long-run. In economic terms, the long-run own-price and cross-price elasticities will be greater than the short-run price elasticities.

Technological advances can contribute to long-run substitution (LRS) in two ways. On the one hand, fabricators and end-users are responsive to technical as well as economic considerations in choosing to use copper versus a substitute. Thus, LRS may be stimulated by changes in the technical and practical feasibility of substitution (i.e., mechanical and physical properties achieved in using a substitute material, safety, ease of handling and storing, size or weight limitations). Technological developments can also alter the relative price ratios at which substitutes for copper may be economical. For example, developments in the last decade in the use of aluminum telephone cables and automobile radiators made aluminum, in theory at least, a realistic substitute at prevailing relative prices.

During the last two decades, world market prices for refined copper have often experienced substantial and at times violent fluctuations. Producers in the industry have at times voiced fears that, regardless of the relative price of refined copper, a lack of stability in that price over time would by itself stimulate fabricators and end-users to substitute other materials for copper.

It seems unlikely, however, that price fluctuations alone encourage LRS for copper. Most copper consumers base their purchasing plans not on daily price fluctuations occurring on a free market, such as the London Metal Exchange, but rather on fluctuations of the monthly or quarterly average price. Short-term fluctuations leading to unusually favorable or unfavorable dates for buying can be expected to cancel each other out in the long-run, regardless of the general buying practices of most firms. Thus, expectations of future long-term relative price trends are likely to be the most important determinant of LRS, as part of long-term investment planning on the part of the user industries.

The fact that long-term substitution in demand can require a period of years as changes in capital equipment take place implies that end-users of copper only "partially adjust" to a new copper price level each year. Their equipment will only depreciate so fast each year and because such equipment will not be replaced immediately, the derived demand for copper is less elastic in the short-run than in the long-run. In the long-run, the end-use industries can fully adjust to new factor prices (price changes being assumed once-for-all) through structural and equipment alterations; hence, demand will be more elastic over the long-run.

4. Short-run and Long-run Adjustments in Demand: Dynamic Demand

The analytical framework for dealing with the short-run and long-run adjustment process in demand, due to the existence of long-run substitution (LRS), is provided by a class of models known as the "adaptive expectations" ("partial adjustment" or "distributed lag") models[8].

The dynamics of the adjustment process can be examined with the aid of Figure VII-3. D_L in Figure VII-3 is the long-run demand schedule of a group of copper using industries and D_s is the short-run demand curve. The curves are assumed to be in equilibrium at (Q_1, P_1). If we assume there is a once-for-all price decrease from P_1 to P_2, the long-run desired quantity demanded would be Q_2. However, in the short-run, equipment and structural rigidities cannot be removed quickly enough. The copper-using industries would therefore end up operating on a new short-run demand curve $\overline{D}_s$, demanding $\overline{Q}_2$, which represents only partial adjustment to the new price situation.

Eventually, as the copper-using industries continue to adjust by altering plant and equipment, their short-run schedule will move outward from $\overline{D}_s$ until it reaches a new short-run demand curve D_s'. Equilibrium is again achieved at (Q_2, P_2) by producers operating at the intersection of the short-run demand curve D_s' and the long-term demand curve D_L.

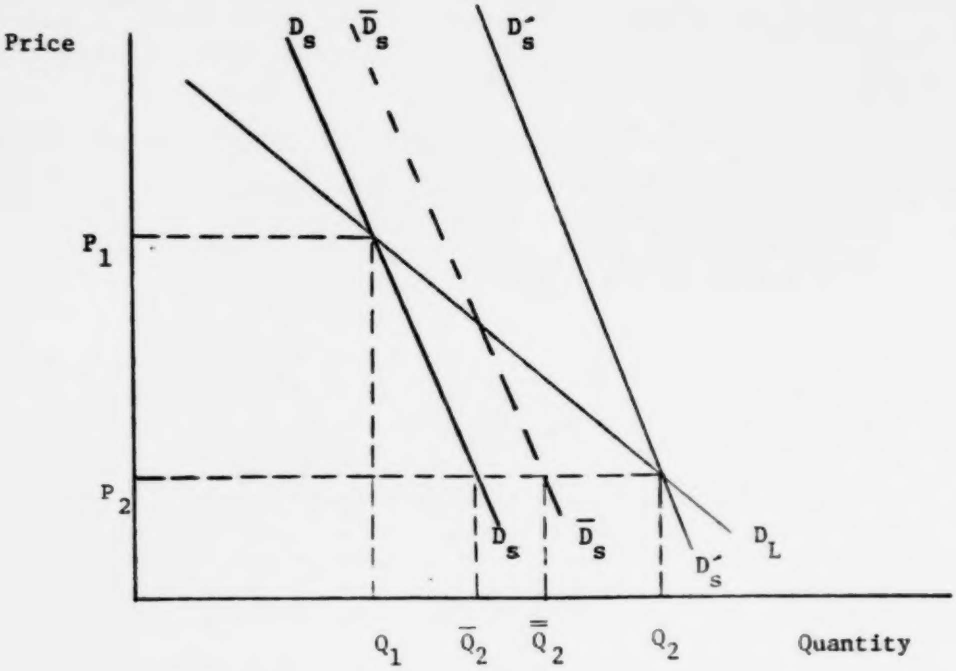
Equation (7) given below, is similar to Equation (5a) except that it relates the desired quantity demanded Q_t^*, by semifabricators, in a given year (rather than the actual quantity demanded Q_t) to prices and activity levels:

$$Q_t^* = \alpha_0 + \alpha_1 P_t + \alpha_2 P^s + \alpha_3 Y. \quad (7)$$

Where the desired quantity demanded and the actual quantity demanded are the same, there is no problem. However, as discussed above, users of copper may not be able to consume Q_t^* (the desired quantity) because of technological constraints. Although, in the long-run, they shall

FIGURE VII-3

THE SHORT-RUN AND LONG-RUN ADJUSTMENT PROCESS IN DEMAND FOR COPPER



move toward Q_t^*, they can only adjust partially to that level of the short-run. We can represent this latter substitution as follows:

$$Q_t - Q_{t-1} = \lambda(Q_t^* - Q_{t-1}), \qquad 0 \leq \lambda \leq 1 \qquad (8)$$

which means simply that the users of the factor (i.e., copper) adjust the level of their actual demand from year t-1 to year t (estimated as $Q_t - Q_{t-1}$) in some proportion λ of the difference between desired demand (Q_t^*) and actual demand during the preceding period (Q_{t-1}). If no technological constraints existed, $\lambda = 1$ and $Q_t = Q_t^*$. In that case, the short-run and long-run demand responses (and elasticities) would be equivalent.

Since "desired" quantities cannot be observed, we can combine Equations (7) and (8),

$$Q_t = \alpha_0\lambda + \alpha_1\lambda P_t + \alpha_2\lambda P_t^s + \alpha_3\lambda Y_t + (1 - \lambda)Q_{t-1} \qquad (9)$$

which can be econometrically estimated because all the explanatory variables are observable.

5. The Relationship between Short-run and Long-run Elasticities

We can see that in Equation (7), α_1 is a measure of the long-run own-price elasticity. If Equation (7) were estimated in log-log form, α_1 would be that elasticity. In Equation (9), $\alpha_1\lambda$ is a measure of the short-run elasticity, since the equation is specified with actual price and actual quantity demanded, rather than desired quantity demanded. If Equation (9) were estimated in log-log form, the short-run elasticity would be $\lambda\alpha_1$. Hence, a knowledge of λ indicates the difference between the short-run own-elasticity (e_{SR})[9] and the long-run own-price elasticity (e_{LR}) of demand, and the two are related as follows[10]:

$$e_{LR}\lambda = e_{SR} \qquad 0 \leq \lambda \leq 1. \qquad (10)$$

Implicit in the short-run/long-run interrelationship is an outward movement in the short-run demand curves. As producers adjust to P_2, D_s moves out to $\bar{D}_s$, $\bar{\bar{D}}_s$, and so on[11] as Q_1 increases to $\bar{Q}_2$, $\bar{\bar{Q}}_2$ etc. (where $\bar{Q}_2$, $\bar{\bar{Q}}_2$ etc. represent actual quantities demanded). Equilibrium is reached when the short-run demand curve reaches $D_s'D_s'$ and equilibrium is again achieved at (Q_2, P_2) by the intersection of $D_s'D_s'$ and D_LD_L.

6. Stochastic Considerations

The above models, which are theoretical specifications attempting to approximate the complexity of derived demand for copper, represent simplified methods of dealing with demand. Before such models can be utilized, they must be estimated. Econometric estimation of demand functions poses some potentially difficult problems, although they are not insurmountable.

One possible difficulty can be the identification problem. The technical aspects of the identification problem are not developed here[12]. Suffice it to say that in models of the size used for the nonferrous metals industries, underidentification is usually not the problem; overidentification is usually the case. Overidentification is a problem of riches; there exist more than enough restrictions on the parameters to yield several different estimates (in small samples) of the parameter. As can be demonstrated[13], two-stage least squares (2SLS) yields consistent and efficient estimates (2SLS was used throughout our analysis, reported in the Technical Appendix).

A second problem involves the presence of lagged endogenous variables. In single equation estimation under conditions of serial correlation[14], the presence of lagged endogenous variables can yield inconsistent parameter estimates. Lagged endogenous variables in a simultaneous system lead to similar difficulties. Needless to say, there exist techniques to deal with the problems. The usual technique utilized in our analysis is the use of instrument to obtain consistent estimates of ϵ and the autocorrelation coefficient ρ[15] and the use of $\hat{\rho}$ to estimate Ω and run GLS.

$$\hat{\beta}_{GLS} = (X'\hat{\Omega}^{-1}X)^{-1}X'\hat{\Omega}^{-1}Y$$

yielding consistent but not efficient[16] estimates of β. Maximum likelihood techniques could be used to obtain asymptotically efficient estimates; however, in our own analysis the efficiency gained was not judged to be worth the extra effort[17].

Finally, there is always a potential "errors in variables" problem that must be discussed. In the typical nonferrous metals markets, demand specification could pose particular problems depending on the availability of data on prices (e.g., actual transactions prices, or list prices) especially in the presence of "rationing" during periods of demand-crunch. It is obvious that in order to estimate the relationship between the price actually paid (transaction prices) by users and the quantity demanded at such prices the analyst must observe the actual quantities and prices. However in some cases, the only price series available are list prices, which can differ considerably from transactions prices depending upon market conditions. In times of a supply glut, for example, sellers may shave their actual transactions prices from list through various rebates, absorption of transportation margins, and various inventory financing schemes. It is this transaction price that is relevant for the analysis of demand for a given commodity. Furthermore, if a commodity is rationed in periods of excess demand, the actual quantity demanded at the observed price can be ascertained only by an exact knowledge of who is rationed and by how much.

When transaction prices and quantities are recorded for markets nearly in equilibrium these considerations are less worrisome. Therefore, it is important for the sample to be defined in such a way as to avoid observations reflecting significant disequilibrium (i.e., rationing) or, alternatively, to attempt to correct for disequilibria, through the use of a dummy variable, for instance. As a rule, transactions prices should always be used. The next best alternative is at least to use a proxy for transactions prices. For example, in the aluminum industry, list prices predominate recorded price series while transactions prices can vary significantly from such list prices. Therefore, to avoid the problem, the price series for secondary refined or for scrap aluminum clippings may be used as proxies for transactions prices under the assumption that the transaction prices will move closely with these two price series. Since, for copper, the transactions prices are as a rule the same as the list prices, these analytical problems are minimized in econometric analyses of copper.

D. ECONOMETRIC ANALYSES OF DEMAND FOR COPPER: SOME RESULTS

There have been a number of econometric studies of the copper industry in recent years, which are discussed more fully in the Technical Appendix which accompanies this volume. We will briefly dwell here on a few of these studies, with emphasis on their econometric analyses of demand for copper. We explicitly consider here the results on short-run and long-run demand elasticities found by Fisher-Cootner Baily (FCB)[18], Charles River Associates, Inc. (CRA)[19], and McNicol[20], along with our own findings (reported in the Technical Appendix). Table VII-7 summarizes the short-run and long-run elasticities that have been estimated.

TABLE VII-7

PRICE AND ACTIVITY ELASTICITY ESTIMATES FROM VARIOUS STUDIES

	Elasticities (At the Mean)			
	Short-Run	Long-Run	Source	Period of Analysis
Own-Price (EMJ Price)	-.47	-.64	ADL (Model)[a]	1950-1973
Cross-Price (Aluminum)	.61	.84		
Activity Variable (FRB Index of Durable Manufacturers)	1.30	1.78		
Own-Price (EMJ Price)	-.21	-.90	Fisher-Cootner-Baily[b]	1950-1958; 1962-1966
Cross-Price (Aluminum)	.24	1.01		
Activity Variable (FRB Index of Industrial Production)	.33	1.40		
Own-Price (EMJ Price)	-.17	-.82	Fisher-Cootner-Baily[b]	1957-1958; 1962-1966
Cross-Price (Aluminum)	.20	.98		
Activity Variable (U.S. Index of Construction Materials)	.15	.73		
Own-Price (EMJ Price)	-.21	-2.88	Charles River Associates, Inc. (CRA)[c]	1950-1967
Cross Price (Aluminum)	.46	6.30		
Activity Variable (FRB Index of Durable Manufacturers	.26	3.56		
Own-Price (EMJ Price)	-.33	-.77	D. McNicol[d]	1949-1966
Cross-Price (Aluminum)	.66	1.57		
Activity Variable (FRB Index of Durable Manufacturers)	.44	1.06		
Own-Price (EMJ Price)	-.12	-.39	D. McNicol[d]	1949-1966
Cross-Price (Aluminum)	.35	1.13		
Activity Variable (FRB Index of Durable Manufacturers)	.32	1.05		

NOTES AND SOURCES:

[a] Refer to the Technical Appendix to this report.

[b] F. Fisher, P. Cootner, M. Baily, "An Economic Analysis of the World Copper Industry," The Bell Journal of Economics and Management Science, 3,2.(Autumn, 1972), 568-609.

[c] Charles River Associates, Inc. (CRA), Economic Analysis of the Copper Industry (March, 1970), pp. 278-315.

[d] D. McNicol, "The Two Price Systems in the Copper Industry," Unpublished Ph.D. dissertation, Massachusetts Institute of Technology (February, 1973), pp. 68-69.

In econometric studies of demand for copper, demand is related basically to the price of copper, prices of substitutes and measures of industrial activity for durable goods. Allowance is also made for inventories, imports and exports in varying degrees. The presence of long-run substitution in demand for copper is generally recognized. Consequently, demand functions are designed to measure short-run and long-run substitution in demand. Although the precise analytical approaches adopted in these studies differ somewhat, they basically utilize the same approach (Koyck-Nerlove) to differentiate short-run and long-run elasticities.

A cursory examination of Table VII-7 does confirm some of the insights introduced earlier in this chapter. For example, 17 out of 18 short-run elasticity estimates indicate substantial inelasticity (or insensitivity) with respect to price and activity. The long-run elasticity estimates are all greater than the short-run estimates, indicating that the response of demand to relative prices and activity is, indeed, more sensitive in the long-run. However, about half of the long-run estimates are still in the inelastic range (i.e., less than 1.0). The long-run elasticity estimates of Charles River Associates, Inc. (CRA) are quite high. There are numerous reasons why the results differ. For example, each of the studies used slightly different estimation techniques[21]. The activity variables utilized in the four studies differ. The aluminum price estimates also differ. Further, the long-run elasticity estimates depend crucially upon the estimate of λ. Interestingly, the major reason for the different long-run elasticity estimates in the various studies is alternative estimates of λ.

Our own econometric analyses of demand for copper, performed as part of the modeling effort reported in the Technical Appendix benefited considerably from previous econometric studies. Equation (9) given above introduced a Koyck-Nerlove type partial adjustment demand model for estimating the price effects for both the long-run and the short-run. Furthermore, the impact of production levels of the industries using copper can be estimated. However, in order to estimate these elasticities, proper data series are required.

An aggregate demand series of domestic semifabricators was presented in Table VII-6. Equation (9) states that the amount of refined copper equivalent demanded by semifabricators is affected by the price of refined copper (P_t), the price of competing substitutes (P_t^S), and the production levels of the consuming industries (Y_t). The price series used for P_t is the deflated EMJ price of copper (i.e., United States producer refinery wirebar, f.o.b.).

We have focused our analysis of copper substitutes on aluminum because of its overriding importance as a potential competitor to copper. The price series used for P_t^s is therefore the monthly average New York dealers' buying price of new aluminum clippings. Production levels of consuming industries have been presented by the Federal Reserve Board (FRB) index of industrial production (durable manufacturers' production). We could have also utilized production levels (or indices) for the semifabricating and fabricating industries. Other analysts have examined some of these alternatives[22].

Estimates derived during this study indicate a 1.0 percent increase in the price of copper will lower demand (consumption) of refined copper equivalent by .47 percent in the short-run and .64 percent in the long-run. Furthermore, a 1.0 percent decrease in the market price of aluminum will stimulate substitution to aluminum (i.e., a decrease in demand for refined copper equivalent of .61 percent in the short-run and .84 percent in the long-run). Also, our income (activity) elasticities are both greater than unity, indicating that a 1.0 percent increase in the production of durable goods manufacturers would generate a 1.3 percent increase in the demand for refined copper in the short-run and 1.79 percent in the long-run[23].

CHAPTER VII

NOTES

1. United States copper production and consumption data developed by the United States Bureau of Mines and the Bureau of Domestic Commerce of the United States Department of Commerce inevitably involve inconsistencies due to differences in reporting, coverage, etc. In order to reconcile these inconsistencies and obtain a consistent accounting flow of copper from production through consumption, the Copper Development Association adjusts inventory data developed by the Bureau of Domestic Commerce. For purposes of our overall materials balancing equation, we have used the adjusted "apparent change" inventory figures of the Copper Development Association; but in analyzing individual inventory components, we have preferred to use the original United States Government data.

2. It is impossible to obtain an entirely accurate breakdown on inventories of primary and secondary refineries as we have defined them. United States Department of Commerce data on refinery stocks of refined copper and scrap reproduced by the Copper Development Association have been used as proxies for stocks held by primary and secondary refiners. Because of the reporting coverage of the Commerce Department's Bureau of Domestic Commerce, some refined copper stocks which we have attributed to the primary producers might logically be part of secondary refinery inventories, while some scrap stocks which we attributed to the secondary refiners might actually be associated with primary refinery inventories. However, these redistributed quantities would without doubt be marginal and use of the Bureau of Domestic Commerce data does not seriously affect the reliability of modeling results obtained.

3. Sir Ronald Prain, Copper: the Anatomy of an Industry (London: Mining Journal Books Limited, 1975), p. 97.

4. Technically speaking, the derived demand schedule will fall out of the first order conditions for cost minimization subject to the production constraint. Derived demand equations are derived for Cobb-Douglas production functions under conditions of perfect and imperfect competition in both factor and product markets.

5. See Henri Theil, Principles of Econometrics (New York: John Wiley & Sons, 1971), pp. 556-573.

6. See Charles River Associates, Inc. (CRA), Economic Analysis of the Copper Industry (March 1970).

NOTES
(Continued)

7. Other forms of logarithmic transformation for estimation purposes include the semilogarithmic

$$Q_t = \alpha_0 + \alpha_1 \log P_t + \alpha_2 \log P_t^s + \alpha_3 \log Y_t + u_t$$

and the inverse semilogarithmic

$$\log Q_t = \alpha_0 + \alpha_1 P_t + \alpha_2 P_t^s + \alpha_3 Y_t + u_t$$

8. The econometric specifications of such models works out to be the equivalent to that of a Koyck lagged model. Of course, the stochastic specification will be different for different models. For a discussion of such models, see Henri Theil, Principles of Econometrics (New York: John Wiley & Sons, Inc., 1971), pp. 258-268.

9. The difference between short-run and long-run elasticity also applies to cross-price elasticities and to the differential impact of Y in Equation (9).

10. This equality can be demonstrated by referring again to Figure VII-3. Let D_L be the long-run demand curve of any group of producers demanding a given factor input and D_s be the short-run curve. Assume the curves are in equilibrium at (Q_1, P_1). Assume further that there is a once-for-all price decrease to P_2. By Equation (7), the long-run desired quantity demanded is Q_2. However, in the short-run, equipment and structural requirements cannot be expanded quickly enough and the producers only demand $\overline{Q}_2$ (i.e., demand is more inelastic in the short-run, as D_2D_2 is the relevant demand curve), where by Equation (8)

$$\overline{Q}_2 - Q_1 = \lambda(Q_2 - Q_1) \qquad (9a)$$

(Note: it should be remembered that Q_2 is desired while $\overline{Q}_2$ is actual).

Here we see that the short-run elasticity is λ times the long-run elasticity since:

$$e_{LR} = \frac{\Delta Q/Q}{\Delta P/P} = \frac{(Q_2 - Q_1)/Q_1}{(P_2 - P_1)/P_1}$$

$$e_{SR} = \frac{\Delta Q/Q}{\Delta P/P} = \frac{(\overline{Q}_2 - Q_1)/Q_1}{(P_2 - P_2)/P_1} = \frac{\lambda(Q_2 - Q_1)/Q_1}{(P_2 - P_1)/P_1} = \lambda e_{LR}$$

NOTES
(Continued)

Hence,

$$\frac{e_{SR}}{e_{SR}} = \lambda \text{ and}$$

$$\frac{e_{LR}}{e_{SR}} = \frac{1}{\lambda} \quad .$$

11. In the second period, $\bar{\bar{Q}}_2$ can be solved as:

$$\bar{\bar{Q}}_2 - \bar{Q}_2 = \lambda(Q_2 - \bar{Q}_2)$$

$$= \lambda\{Q_2 - [Q_2 + \lambda(Q_2 - Q_1)]\}$$

$$= \lambda(1 - \lambda)\ (Q_2 - Q_1).$$

Likewise,

$$\bar{\bar{\bar{Q}}}_2 - \bar{\bar{Q}}_2 = \lambda(Q_2 - \bar{\bar{Q}}_2)$$

$$= \lambda\{Q_2 - [\bar{Q}_2 + \lambda(Q_2 - \bar{Q}_2)]\}$$

$$= \lambda\langle Q_2 - \{Q_1 + \lambda(Q_2 - Q_1) + \lambda[Q_2 - (Q_1 + \lambda Q_2 - \lambda Q_1)]\}\rangle$$

$$= \lambda\langle Q_2 - Q_1 - \lambda Q_2 + \lambda Q_1 - \lambda Q_2 + \lambda Q_1 + \lambda^2 Q_2 - \lambda^2 Q_1\rangle$$

$$= \lambda Q_2 - \lambda Q_1 - \lambda^2 Q_2 + \lambda^2 Q_1 - \lambda^2 Q_2 + \lambda^2 Q_1 + \lambda^3 Q_2 - \lambda^3 Q_1$$

$$= \lambda(Q_2 - Q_1) - 2\lambda^2 Q_2 + 2\lambda^2 Q_1 + \lambda^3 (Q_2 - Q_1)$$

$$= \lambda(Q_2 - Q_1) - 2\lambda^2 (Q_2 - Q_1) + \lambda^3 (Q_2 - Q_1)$$

NOTES
(Continued)

Since,

$$AB - 2A^2B + A^3B = AB(1 - 2A + A^2)$$

and since

$$(1 - 2A + A^2) = (1 - A)^1$$

then

$$AB - {}^2A^2 + A^3B = AB(1 - A)^2 = A(1 - A)^2B.$$

Hence, setting $\lambda = A$ and $(Q_2 - Q_1) = B$, we have

$$\bar{\bar{\bar{Q}}}_2 - \bar{\bar{Q}}_2 = \lambda(1 - \lambda)^2 \quad (Q_2 - Q_1).$$

12. See Franklin M. Fisher, The Identification Problem in Econometrics (New York: McGraw-Hill Book Company, 1966).

13. Henri Theil, op. cit., Chapter 10: E. Malinvaud, Statistical Methods of Econometrics (Amsterdam: North-Holland Publishing Company, 1971), Chapters 16-20.

14. Serial correlation will be particularly likely in time-series analysis. Further, it is well known that the use of some lag form induces serial correlation even if it were not present in the unlagged specification. For a discussion of the serial correlation incuded by the Koyck lag, see Henri Theil, op. cit., pp. 258-261.

15. Usually only first order serial correlation was assumed.

16. The information matrix is not block diagonal.

17. This discussion presupposes familiarity with the terminology and issues of econometric mentioned.

18. F. M. Fisher, P. H. Cootner and M. N. Baily, "An Econometric Model of the World Copper Industry", The Bell Journal of Economics and Management Science, 3, 2 (Autumn, 1972), pp. 568-609.

19. Charles River Associates, Inc., (CRA), Economic Analysis of the Copper Industry (March, 1970). Also see An Econometric Model of the Copper Industry (September, 1970); Forecasts and Analysis of the Copper Market (May, 1973); and Policy Implications of Producer Country Supply Restrictions: The World Copper Market (August, 1976).

NOTES
(Continued)

20. David L. McNicol, "The Two Price Systems in the Copper Industry", Unpublished Ph.D. Thesis, Massachusetts Institute of Technology, February, 1973. Also see his "Two Price Systems in the Copper Industry", The Bell Journal of Economics, 6, 1 (Spring, 1975), pp. 50-73.

21. For details, see the Technical Appendix to this report, Supporting Paper 1, "Economic Analyses of the Copper Industry: General Theoretical Considerations and Critical Review of Selected Empirical Studies".

22. For example, an index of construction activity was examined by Fisher-Cootner-Baily. See Fisher-Cootner-Baily, op. cit.

23. As reported in the next chapter, the historical presence of a two-tier price system for copper has prompted the hypothesis of a rationing behavior on the part of the domestic primary producers. To account for the possible effects of such hypothesized rationing behavior, we performed alternative estimates of demand elasticities for differing sample periods which did not include rationing years. This yielded similar estimates for the short-run elasticities. However, the long-run elasticities differ since the estimate of λ did change. Information on rationing is quite inadequate to introduce it effectively into the analysis. None of the analyses in Table VII-6 appear to have accounted for the possible presence and hence effects of rationing.

VIII. PRICES

A. INTRODUCTION

An adequate understanding of the manner in which supply and demand forces have interacted in the copper industry in the past cannot be attained without a firm grasp of the rather complex set of institutional arrangements which characterize copper markets, the process of price formation among firms in the industry, and, as a directly related matter, the existence of the "two-price system" for copper which in the past has been a source of controversy both in terms of the reasons underlying it and in terms of its role, if any, on the pricing behavior of the domestic primary producers. This chapter therefore focuses on these three closely interrelated subjects.

Historically, copper has been marketed at prices based on a number of different systems, some of them quite complex. Nevertheless, two basic pricing channels can be distinguished, the producer prices and prices related to quotations on a metal/commodity exchange. Producer prices are prices set independently by the major primary United States and Canadian producers at which primary refined copper is sold in the United States. During the postwar period, about 75 percent of all refined copper production in the United States has been sold at the domestic producers' price. Prices related to quotations on a metal/commodity exchange refer to prices at which copper is sold internationally (outside North America) by most producers most of the time, related through various formulas to prices prevailing principally on the London Metal Exchange (LME). The LME and the New York Commodity Exchange (COMEX) are the two organized metal exchanges (markets). Of the two, the LME is generally considered to be the more important in terms of turnover, physical deliveries, and its influence on the pricing of copper in general.

Most of the "formulas" for pricing copper that are found on long-term contracts are related, in one way or another, to LME prices, since LME prices are generally considered to reflect, without delay, changes in the supply and demand situation worldwide. It is important to emphasize that the LME and COMEX are basically hedge and speculative, rather than physical markets.

Prices prevailing in the United States, other than the primary producers' prices, can be grouped under the collective title of "outside" market prices, which encompass all trade in copper within and entering the

United States (apart from sales made within the United States by the primary producers) at prices other than the domestic producers' prices (which would include prices tied to the LME or COMEX quotations). The outside market encompasses the secondary industry (including scrap dealers and secondary refiners), some of the smaller domestic producers of refined copper selling at premiums over the price of the major domestic producers, and the merchants who generally buy and sell copper outside the principal producer-consumer channels.

As we have seen, demand for copper is quite inelastic in the short-run, and the supply of copper is basically slow, characterized by long adjustment periods. Hence, wide swings in demand over the business cycle in industrial countries, combined with speculative activity in the very short-run on the two organized commodity exchanges, have contributed to the volatility of copper prices internationally. However, United States domestic producers' prices, while lagging LME prices, have generally been considerably more stable. Generally speaking, the domestic primary producers, in response to persistent demand shifts have tended to change their prices only slowly and not by the magnitude often experienced by the LME price, such that the producers' prices have generally remained well below LME prices during periods of strong-demand and above LME prices during periods of weak demand. This resulted in the existence of a two-price system for refined copper in the postwar period which was characterized by a wide divergence between the outside market price for copper (i.e., the LME price) and the domestic producers price. In periods of rising or excess demand, the participating producers chose to keep the prices low and ration their available copper supplies to customers rather than raise the prices. There appears to be no complete, simple, logical explanation or set of explanations for the apparent rationing behavior of the principal United States and foreign producers during periods of excess demand and hence of the two-price system. All of the proposed explanations are either logically inconsistent and/or are unable to explain certain "anomalous" behavior.

A combination of factors appears to have had substantial restraining influence on the pricing decisions of the domestic primary producers. These factors include the actual (as well as the expected) threat of long-run substitution from aluminum, some competition from secondary producers, the apprehension that domestic customers might shift to overseas suppliers if the domestic producers' price remained above the LME price over a prolonged period, the presence of United States government stockpiles and the threat of government intervention.

The sharp rise in copper prices worldwide in 1973-1974, which occurred as part of a more general "commodity boom" affecting nonfuel primary commodities at a time when OPEC oil prices were quadrupled, was caused by a unique juxtaposition of factors, including simultaneous economic growth in many countries, strikes and political unrest, constraining supply, and widespread speculation brought about by fears of supply cutbacks, inflationary expectations and considerable uncertainty surrounding exchange rates.

For purposes of modeling the United States copper industry, the existence of the two-price system raises two basic questions. The first pertains to the interaction between the LME prices and the domestic copper prices (including both the primary producers' prices and the "outside market" prices). The causal channels here are quite complex and no simple answers can be readily found. Our approach basically takes the point of view that, everything else being equal, the LME prices more directly or immediately influence the domestic "outside" market prices and affect the producers' prices in a more indirect and delayed manner. The effect on the primary producers' prices is both via price and supply responses generated on the "outside" market (which theoretically would have some influence on the production decisions of the primary producers) and via the conditioning of the perceptions of both the primary producers and the independent fabricators as to the current or continued strength of the world copper market, thus affecting price-output, inventory and purchasing decisions simultaneously.

The second question relates to the responsiveness of net United States international trade in copper to the "spread" between the LME and the producers' price or changes in this price "spread". Our basic finding is that, in the past, net United States international trade in copper (i.e., exports minus imports) has over the longer-run remained remarkably insensitive to the existence, magnitude, or the rate of change of the spread. Consequently, the modeling of net international trade in copper (i.e., net imports or net exports) presents special difficulties, for lack of discernible trends. This, combined with the fact that United States net imports or net exports in copper have been normally quite small in the past, would suggest that the modeling of net imports or net exports in copper under ordinary circumstances requires relatively little analytical emphasis.

Recent developments, however, suggest that such a conclusion might be unwise, as far as forecasting into the medium-term or the distant future is concerned. The reason for this is that the observed historical patterns have recently undergone a dramatic reversal. Since late-1974, the primary producers' price has remained above the LME price. This certainly is not the first time such a development has occurred in the postwar history of the two-price system. Nevertheless, it has given rise to widespread speculation, currently gaining increasing acceptance in the light of the depressed economic conditions facing the United States copper industry, that the current two-price system, with the primary producers' price above the LME prices, will continue into the future. It is believed that an unavoidable consequence of such a development would be a substantial rise in imports into the United States, low domestic copper prices resulting from increased foreign competition and a relatively depressed domestic copper industry. In this respect, the sharp rise in imports, for example in 1976 from such countries as Zambia and Chile, is thought to be indicative of possible future upsurge in United States imports. Such a reversal of historical patterns would require a shift in the basic perception of the domestic semifabricators, including the downstream subsidiaries of vertically integrated major domestic copper producers, that they can achieve both short-run and long-run cost minimization by switching to foreign suppliers. The rest-of-the-world and the domestic copper markets would then equilibrate, which in turn implies that the price "spread" would virtually disappear (except for transportation and distribution costs) or would at any rate narrow down significantly.

Such a view of an emerging "state of the world" is conditioned by two basic factors or perceptions. The first is that quite low macroeconomic recovery and growth in especially the European OECD countries, as currently projected, will mean continued weak world demand for copper. Continued weak demand, together with the large size of current copper inventory stocks worldwide, would drive down the LME prices, even if restraints on production were to be assumed. The second reason extended in support is that the major copper exporting developing countries (e.g., Zaire, Zambia, Chile, etc.) face substantially increased foreign exchange requirements not only to pursue minimal development objectives but also to finance their mounting external debts (including that incurred to finance copper production) and to pay for their significantly higher energy import bills. This means, the argument goes, these countries will continue to produce copper at or near full capacity with little regard to copper price movements. Their production decisions, even in the face of depressed world copper prices is explained as follows. Their cost of production consists of both foreign and domestic cost components, incurred, respectively, in a basket of convertible foreign currencies (e.g., interest payments, etc.) and in domestic currency (i.e., to pay for domestically utilized factors of production). In order to translate these two basic cost components into "true" national costs, they respectively need to be valued not in strictly financial terms, which would reflect "distorted" existing market prices, but rather in an economic sense at their estimated scarcity values (shadow prices). In such a calculation, the relatively large domestic cost component would become quite low, by virtue of the relatively low shadow prices that would be assigned to most of the domestic factors of production (e.g., labor) which are in relatively abundant supply. Consequently, the weighted average of the two cost components would help define the true national unit cost of production. By contrast, on the national benefit side, unit foreign exchange earnings would be imputed a very high scarcity value (shadow price). Consequently, even at quite low LME prices, these countries would enjoy a favorable national benefit-cost ratio. This, rather than normal profit or rate of return considerations, would serve as the basis for their pricing-production decisions over the next few years, given their existing productive capacity.

This general argument, which has a certain logical appeal, explains mostly current or short-run market behavior and is conditioned basically by the current economic conditions facing the copper industry both domestically and in the rest of the world. However, strong economic recovery both in the United States and in the other industrialized countries (particularly in the European countries), together with, for example, renewed growth of electric utility-related construction activity could strengthen copper demand to the extent of restoring the historical pattern.

Over the long-run, the costs of production provide a rising floor on copper prices, such that, the long-run price of copper tends to equal the price that is sufficient to induce continued investment. This price, which may be regarded as the long-run economic cost of producing copper, is thought to have increased sharply in recent years after having remained fairly steady over a long period. Thus, if the long-run copper price is not sufficient to induce continued investment, such investment would cease until rising demand and capacity shortages result in price levels sufficiently high to induce new productive investment.

B. COPPER PRICING MECHANISM

Historically, copper has been marketed at prices based on a number of different systems, some of them quite complex. Today, the basic complexity of copper pricing mechanisms remains, in the sense that the distribution and pricing of copper supplies to copper consumers is characterized by many pricing/institutional arrangements. Nevertheless, two basic pricing channels can be distinguished.

- Producer prices: These are prices set independently by the major primary producers at which primary refined copper is sold. In the United States, the domestic producers' price is a set of nearly uniform price quotations used by the major United States producers and, for a good part of the postwar period, by Noranda, one of the Canadian producers, for sales in the United States.

- Prices related to quotations on a metal/commodity exchange: These are prices at which copper is sold internationally (outside North America) by most producers most of the time, related through various formulas to prices prevailing principally on the London Metal Exchange (LME). The LME and the New York Commodity Exchange (COMEX) are the two organized metal exchanges (markets). Of the two, the LME is generally considered to be the more important in terms of turnover, physical deliveries, and its influence on the pricing of copper in general: most of the "formulas" for pricing copper that are found on long-term contracts are related, in one way or another, to LME prices, since LME prices are generally considered to reflect, without delay, changes in the supply and demand situation over the entire world. However, COMEX handles a wider variety of metals, and it also provides facilities for trading other commodities[1]. It is important to emphasize that the LME and COMEX are basically hedge and speculative, rather than physical markets. Their principal function is, hence, to provide hedging facilities for both producers and fabricators against losses resulting from price changes rather than as markets for spot sales for physical deliveries. COMEX's trading rules virtually preclude its use as a physical market. However, the LME can be, and sometimes is, used as a physical market, but even in Europe its role as a physical market is very limited.

In addition (and related) to these two basic copper pricing channels, a number of others can be distinguished, under the collective title of prices prevailing in the "outside market". The term "outside market", with reference to copper markets in the United States, is sometimes used to describe all trade in copper apart from sales made by the primary producers. The outside market encompasses the secondary industry (including scrap dealers and secondary refiners), some of the smaller domestic producers of refined copper selling at premiums over the price of the major domestic producers, and the merchants. Defined more broadly, the "outside market" includes, with reference to the United States, transactions in physical copper on the LME and COMEX plus imports based on LME quotations.

It might be noted, in this connection, that the metals merchants are trading firms which typically trade in all types of copper products, as well as in various metals, and organize the refining of numerous small lots of material (i.e., scrap, secondary blister, and the output of small mines).

In the United States, refined copper has been bought and sold on average in the following proportions during the postwar period.

- About 76 percent of average annual consumption has been sold by United States primary producers at the domestic producers' price;
- About 13 percent of average annual consumption has been marketed by the principal secondary refiners (e.g., Amax, Cerro Corporation[2], Southwire Company, Reading Industries, Inc.) at their own established price (i.e., explicitly if sold to others or implicitly, in terms of internal company "transfer prices", if shipped to their own semifabricating/fabricating subsidiaries or affiliates) generally reflecting the prevailing price for copper scrap plus operating margins;
- The remaining 11 percent of consumption on an average annual basis has consisted of imports from foreign producers based on LME quotations and copper handled by United States metals merchants, mostly sold at the LME price or at a price closely reflecting that price.

Because movements in the price of domestic scrap tend to follow closely movements in the LME Price, however, on average 24 percent of refined copper consumption in the United States (including imports of refined copper) can be said to have been marketed on the basis of LME prices.

The great bulk of refined copper sales by the major producers are handled through their own subsidiary sales agencies. Some sales agencies handle not only the refined output of their parent companies, but also copper refined by several other domestic and foreign primary producers, and it is not uncommon for the output of a small primary producer to be sold through the sales agency of a larger producer. Sales by these agencies represent current orders by buyers for future physical delivery of copper at an agreed upon price.

1. The United States Producers' Price

Since shortly after World War II, the major United States primary producers have, in effect, used a common basis for determining the price at which they sell refined copper to affiliated and independent fabricators within the United States[3]. This domestic producers' price has represented a common set of price quotations for delivery of wirebars, ingots, and ingot bars to any consuming destination within the continential United States[4]. Cathodes have been available at a slight discount, indicating the absence of melting and casting costs. Cakes and billets, on the other hand, have sold at premiums which cover additional casting and fabricating costs. In 1973, two major producers began referring to their cathode price as the standard producers' price. In part, this reflects the increasing amount of cathode copper produced by electrowinning from hydrometallurgical treatment of oxide copper. Also, the Cost of Living Council used the cathode price in setting ceilings on refined copper prices in the United States in December 1973.

Currently, the following are the principal United States domestic producer price quotations:

- MW U.S. producer delivered: This is a daily weighted average producers' price quotation published by Metals Week (formerly E/MJ Metal and Mining Markets) based on United States mine production and current selling prices of United States producers, quoted on a delivered wirebar basis[5].

- MW U.S. producer refinery: This is a daily f.o.b. refinery quotation, also published by Metals Week, which represents the producers' delivered price quotation minus a standard shipping cost. This Metals Week price, or its weekly or monthly arithmetic average, published in Engineering and Mining Journal (E/MJ), is normally referred to when speaking of the domestic producers' price for refined copper.

- MW U.S. producer cathode: This daily quotation, published by Metals Week, is an estimated weighted average based on United States mine production and published prices for delivered full-plate cathodes.

- American Metal Market domestic delivered: This represents an additional price quotation for domestic primary refined copper published daily in the American Metal Market; the monthly arithmetic average of these quotations is published annually in Metal Statistics.

United States producers usually sell on the basis of the price prevailing on the date of shipment, regardless of when the buyer placed his order. Some sales, however, are made at the average weekly or monthly price quotation as published in E/MJ or American Metal Market; other sales may be made at a firm price prevailing on the date of the sale.

Early in January, 1976, Kennecott, the largest domestic primary producer, announced that as of January 1, 1976 it had stopped producing, supplying, marketing and quoting electrolytic copper wirebar, on the grounds that this reflected the trend for increasing use of cathode instead of wirebar and increasing demand for copper rod[6]. Also in early 1976, two primary producers, Duval and Copper Range, switched their pricing of copper back to the producers' price basis following a brief period of experimentation since 1974 during which Duval had sold on an average price basis and Copper Range had been selling its Lake brand copper on the basis of copper futures contracts traded on the COMEX[7].

2. The Copper Exchanges: The LME and COMEX[8]

Of the two exchange markets on which copper is quoted, the LME is certainly the more important in terms of volume of transactions, physical deliveries, and influence on world copper prices generally. As has already been noted, producers' prices outside the United States tend to follow LME quotations rather closely and long-term contracts employ a variety of formulas for pricing copper related to LME prices. Although there is frequently a price differential of several cents per pound for the same type of copper between the two markets as a consequence of the time and cost of shipping copper, government trade controls, and other factors, arbitrage transactions between the COMEX and the LME tend to limit the amount of the differential. There are a number of important differences in the two markets that require explanation.

a. The London Metal Exchange (LME)

The LME dates from 1882, although copper and other metals had been quoted in London much earlier. During World War II and the immediate postwar period, when the government controlled the price of strategic metals, the exchange was closed; but it reopened in 1953, and since that time a steady increase in activity has been noted.

The LME deals exclusively in nonferrous metals--copper, lead, zinc, tin and silver. Two copper contracts are traded on the LME: one for electrolytic wirebar, and one for electrolytic cathode[9]. Cathodes normally trade at a discount under wirebar, reflecting conversion costs. Contracts are on a cash ("spot") or three-months ("ninety days") basis, minimum trading units being multiples of 25 metric tons. Dealings on the LME are not simply paper transactions. Purchasers can always obtain delivery of metal on the day agreed upon (and in the case of spot transactions, the following day) at any of the registered LME warehouses at the seller's option. Warehouses and wharves approved by the LME for delivery and storage of metal traded on the exhcange are located in London, Birmingham, Liverpool, Manchester, Birkenhead, Hull, Newcastle-on-Tyne, Swansea and Glasgow in the United Kingdom; Rotterdam in the Netherlands, Bremer and Hamburg in Germany; and Antwerp in Belgium. Insistence on delivery has remained paramount and is reflected in the fact that contracts may not contain any force majeure provisions.

Trading on the LME takes place through representatives of the currently 28 registered member companies, known as "ring traders", who are seated in a circle around the exchange floor and who make bids and offers to each other across the ring. Deals are made when a bid or offer is accepted and contracts are issued promptly. Dealers may hold a position in the metal traded on any market day between the current day and three months forward, with the final day for liquidation being the last market day before the contract matures. Dealing members accept the responsibility of honoring their own contracts[10].

Two sessions operate daily, in the morning and in the afternoon, Monday through Friday. The morning session, lasting 60 minutes and known as the "Official Session", is followed by 20 minutes of kerb trading (i.e., dealings outside the market). The afternoon session, lasting 50 minutes and called the "Unofficial Session" is followed by 15 minutes of kerb trading. At each session, there are two five-minute rounds of trading in each metal. A deal is regarded as having been concluded when a bid or offer is verbally accepted. Details are noted by clerks of the buying and selling ring traders involved in each transaction, and contracts are exchanged before noon of the following trading day. The official LME price for each day is based on the prices asked and bid after the last actual trade in each metal at the end of the morning[11].

The LME price, although it is determined by a small number of transactions daily, is important as it has been used as a transaction price by a number of major producers. During the postwar period, with the exception of five and one-half years, it has been the policy of the Anglo-American Corporation (AAC) and Rhodesian Selection Trust (RST), both with properties in Zambia, to sell at the LME price[12]. Union Miniere du Haut Katanga (UMdHK), with properties in Zaire, also generally sold at a price closely related to the LME price. Further, sales of Canadian and Chilean copper made outside the United States have usually been based on the LME prices.

b. The New York Commodity Exchange (COMEX)

The COMEX copper contract are for 25 short tons of either electrolytic wirebar, high conductivity fire-refined copper (HCFR), Lake Copper, electrolytic cathode, or 99.88 percent fire-refined copper, all specified according to American Society for Testing Materials (ASTM) standards[13]. Electrolytic cathodes and high conductivity fire-refined (HCFR) copper may be substituted at fixed differentials.

Price movements on COMEX have a daily limit of three cents per pound for all trading months except the spot months. This limitation, together with the system of trading for delivery in seven selected months and at any day during the month at the seller's option, is designed to prevent the price from being disproportionately affected by a few large transactions. However, this system complicates the use of COMEX as a hedging medium and as a basis for establishing prices for contracts outside the market. It also complicates the problem of comparing LME and COMEX spot and forward prices and/or arbitrage between the two exchange markets. However, formulas have been adopted to compare the prices in the two markets in a manner which will eliminate to the maximum degree possible the distortions arising from the different trading and delivery arrangements.

On the COMEX, cathode and the lower grades of fire-refined copper are traded at a discount below electrolytic wirebar. Since the cost of casting cathode into wirebar and the actual market value of lower grade fire-refined is generally more than the discount, it is to the producers' advantage to deliver these lower grades against COMEX contracts. Hence, the COMEX warehouses contain mainly the lower grades of copper. Such grades serve as a source of direct supply to brass mills and foundries. Other United States semifabricators tend to purchase wirebar from merchants, whose prices fluctuate at a premium above the COMEX quotations. By pricing their copper in close relation to COMEX prices, both merchants and consumers are able to employ the COMEX for hedging purchases and sales for future delivery against price changes.

In summary, COMEX is considerably less important in world copper markets than is the LME. Like LME, COMEX is basically a hedge and speculative market, but COMEX is even less of a physical market than LME, and the COMEX price is not generally used for sales on the "outside" market. Arbitrage between the LME and COMEX generally keeps the prices close together.

3. The "Outside Market": Secondary Refiners and Role of the Merchants

a. Secondary Refiners

The term "outside market" has often been used to denote all trade in copper in the United States other than sales of the major United States primary producers. The term has been so applied, to delineate more sharply the dominant role played by the major primary producers in providing the bulk of refined copper supplies at domestic producers' prices to United States fabricators.

Although refined copper within the United States can be bought on the outside market at a number of different prices, including the LME spot and forward price, the COMEX price, the United States merchants or dealers' price, and the custom smelters/refiners and/or secondary refiners price, the two most important price bases at which the bulk of outside market sales of refined copper are quoted have been the LME price and the price set by custom smelters/refiners and/or secondary refiners. We should repeat, at this point, the important distinction between custom and toll smelting/refining, applicable to both primary and secondary smelters/refiners. Custom smelting/refining refers to purchasing ores, concentrates or scrap from other producers for own-account smelting and refining. Toll smelting/refining, on the other hand, refers to smelting/refining for a fee and then returning the resulting metal to the original owner (e.g., mining companies, merchants, etc.) for marketing. In this sense, both primary and secondary smelters/refiners may be engaged in custom smelting/refining as well as in toll smelting/refining. Further, while it is generally correct to say that the output of a secondary smelter/refiner, regardless of whether it operates on a custom or toll basis (or both), is most probably sold on outside market prices, such a statement would be incorrect for a primary smelter/refiner.

This distinction brings up the role and classification of Asarco based on its pricing behavior, which is often incorrectly understood in current studies of the United States copper industry. Prior to August, 1967, Asarco sold at least some proportion of its output at a "custom smelter" price published in both Metals Week and Engineering and Mining Journal. After August, 1967, Asarco suspended the practice of quoting a custom smelter price, and generally followed producers' price quotations in its sales. We understand that even prior to 1967, less than 50 percent of Asarco's output was actually sold at the custom smelter price.

Given the facts pertaining to Asarco's position prior to 1967, plus the fact that Asarco has behaved essentially as a primary producer since 1967, we have classified Asarco as a primary producer in this study and have included Asarco's output in the figures for total primary refined copper production in the United States sold basically at the producers' price during the postwar period.

With Asarco thus excluded, Amax and Cerro[2] have accounted for at least 75 percent of United States secondary refined copper production from scrap in most years since 1946, with the remainder divided among a number of other firms (e.g., Reading Industries, Inc., Southwire Company, Chemetco, Inc.). These two firms can thus be considered "representative" of the United States secondary copper industry.

Amax and Cerro sold their refined copper output on their own individual pricing basis. We have estimated that refined copper sold on this basis accounted for an average of about 13 percent of total refined copper supplied each year between 1947-1974 and have held about 11 percent of domestic refinery capacity during this same period.

Because both Amax and Cerro have depended heavily on the copper scrap market for material inputs in the production of refined copper, the profitability of their operations has been dependent on maintaining flexible pricing policies which enable them to respond to fluctuations in the price of copper scrap.

In our analysis, we have not had access to a recorded historical price series for sales by Amax and Cerro; hence, as a second-best approximation, we have developed an estimated price series based on the dealers' buying price for #2 heavy copper scrap[14] and estimated annual processing costs and margins for the two custom refiners which reflect a "fictitious" price series in the sense that it does not necessarily represent actual prices charged by these custom refiners at any one point in time, but rather an approximate estimate of their average pricing behavior over the study period.

b. Role of the Merchants[15]

The remaining 11 percent of annual United States refined copper consumption has generally come from one of the following sources: directly purchased imports from foreign producers, sales on the London Metal Exchange, or purchases from United States metals merchants. With the exception of refined copper sold in the United States by Noranda (a Canadian company) at the domestic producers' price, imported refined copper and merchant copper has generally been sold in the United States on the basis of the price prevailing on the London Metal Exchange or at a price closely reflecting that price.

The major producers have refrained from selling copper in large quantities on the LME not only because their customers often require nonstandardized grades and shapes of copper to suit their specific needs, but also because the Standard Contract on the LME requires physical delivery of the copper in European warehouses, a requirement which is economically prohibitive for selling copper to customers in other parts of the world. Moreover, the major producers normally insist on the inclusion of a force majeure clause in their sales agreements; such clauses are not permitted under the LME contract system.

In this connection, it should be noted that merchants generally buy and sell copper outside the principal producer-consumer channels. Merchant copper traded in the United States is related to the COMEX price. Merchants for the most part do not invest in production facilities, but they can and will hold or finance stocks. In the United States, where there is more integration in the copper industry, merchants may be experiencing somewhat less scope for their activity than in Europe. For one thing, COMEX has a smaller physical turnover than the LME, and although its facilities for hedging and speculating are as developed as those to be found in London, it is not especially oriented toward the international market.

Merchants tend to make extensive use of independent refineries. They also buy a great deal of scrap for refineries handling secondary materials. Many of the physical deliveries on the LME result from the transactions of the merchants; and, by the same token, they carry out arbitrage operations on a worldwide basis. They are usually busiest when the demand for copper is highest, since during these periods more copper than ever will come from the smallest mines (i.e., mines that under normal circumstances are only marginal producers and possibly have not committed their production to any given refinery) or scrap. There are also periods when buyers or sellers are most likely to misjudge requirements and thus need the service of merchants.

C. COPPER PRICES SINCE WORLD WAR II

The significant aspects of pricing behavior in the postwar copper industry can be adequately described by focusing on the history of the LME and domestic producers' prices. As a general rule, LME price movements have been relatively volatile and sensitive to speculative pressures and short-run shifts in copper demand and supply. By contrast, the producers' price has tended to change only slowly, usually lagging significant trends in LME prices by several months.

1. Review of Price Movements

Table VIII-1 provides average annual figures for the E/MJ domestic refinery price, the LME spot price, the price for #2 heavy copper scrap (#1 heavy copper scrap prior to 1956) and the United States producer refined aluminum (list) price, over the 1950-1975 period, all expressed in nominal or current dollar terms. Figure VIII-1 shows the relationship, over the same period, between the LME prices and the United States domestic primary proudcers' prices.

The essential facts concerning price movements and the pricing behavior which underlay them can be fairly easily grasped by dividing the entire study period into a number of smaller periods on the basis of changing supply and demand conditions in the copper industry and the particular response of copper producers to those changing conditions.

- 1947-1953: This was a period marked by government controls of both the LME and the United States producers' prices. The LME price was administered by the British Government until August, 1953. A price ceiling on the domestic producers' price was in effect from January, 1951 to February, 1953 in response to Korean War requirements.

- November, 1953-July, 1956: This period marked the first so-called "two-price system" for refined copper. A sudden and excessive increase in the demand for copper led to a rapid rise in the LME price; the domestic producers' price, on the other hand, was kept substantially below the market-clearing level by United States producers, who rationed their customers. One foreign producer, RST, also sold copper at substantially below the LME price.

- July, 1956-early, 1964: Except for a brief period of rising demand in 1958-1959, this was a period of generally slack world demand for refined copper, characterized by decline of relative stability in both the domestic producers' and the LME prices and general equilibrium between the two price series (with LME prices remaining below the domestic producers' prices, after accounting for the differential cost of tariffs and transport).

- Early 1964-late 1970: This was a period of the second and third "two-price system", characterized by excess demand for copper, a very dramatic increase in the LME price, and a wide differential between the higher LME price and the producers' price, where the producers' price stayed well below the LME price.

  The second and third two-price systems are distinguished principally by the difference in the group of firms which participated in selling copper below the free or open market price. During the second two-price system between January, 1964 and March, 1966,

TABLE VIII-1

PRICES OF REFINED COPPER, COPPER SCRAP AND REFINED ALUMINUM IN THE UNITED STATES, 1947-1976

(yearly averages, cents per pound)

Year	U.S. Producer Refined Copper[a]	LME Refined Copper[b]	Scrap Copper[c]	U.S. Producer Refined Aluminum[d]
1947	21.0	23.5	16.2	15.0
1948	22.0	24.1	17.3	15.7
1949	19.2	21.9	13.9	17.0
1950	21.2	22.3	17.7	17.7
1951	24.2	27.5	21.3	19.0
1952	24.2	32.3	19.0	19.4
1953	28.8	32.2	22.4	20.9
1954	29.7	31.3	24.5	21.8
1955	37.5	43.9	33.6	23.7
1956	41.8	41.0	31.6	24.0
1957	29.6	27.4	20.1	25.4
1958	25.8	24.8	17.6	24.8
1959	31.2	29.8	22.6	24.7
1960	32.1	30.8	21.2	26.0
1961	29.9	28.7	21.8	25.5
1962	30.6	29.3	21.6	23.9
1963	30.6	29.3	22.2	22.6
1964	32.0	44.0	26.0	23.7
1965	35.0	58.6	34.5	24.5
1966	36.2	69.1	44.7	24.5
1967	38.2	51.2	33.2	25.0
1968	41.8	56.0	32.8	25.6
1969	47.5	66.3	42.9	27.2
1970	57.7	62.9	39.5	28.7
1971	51.4	49.3	27.6	29.0
1972	50.6	48.5	39.0	26.4
1973	58.9	80.8	50.2	25.0
1974	76.6	93.1	54.9	34.1
1975	63.5	56.1	33.9	39.8
1976	68.8	63.9	51.6	44.3

NOTES AND SOURCES:

[a] U.S. producer refinery wirebar f.o.b. (i.e., U.S. producer delivered price minus shipping cost; the shipping cost was 0.9¢/lb. effective August 1, 1976): Metals Week, Engineering and Mining Journal.

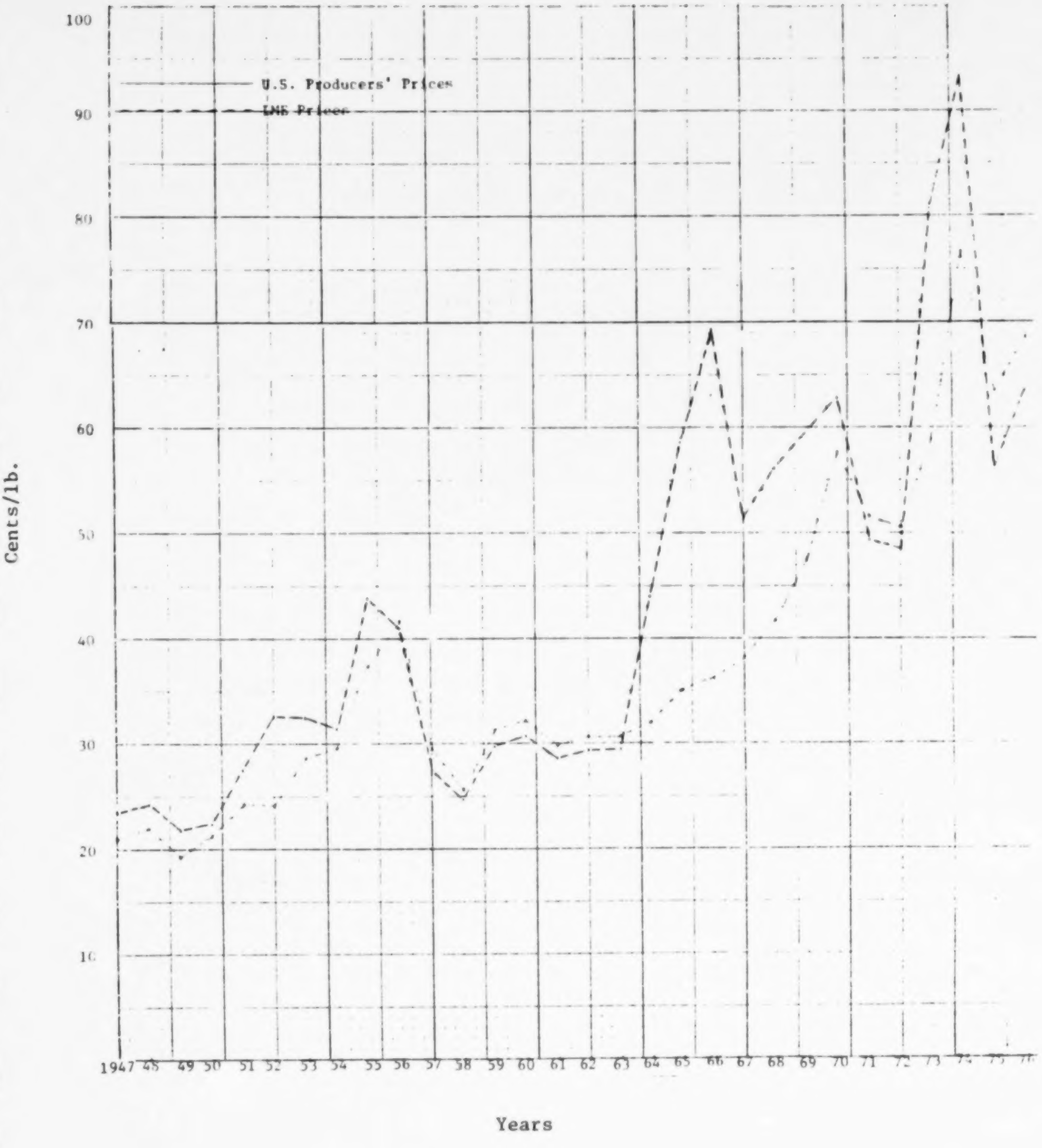
[b] Official morning session prices on the London Metal Exchange; electrolytic wirebars, monthly average, settlement price: Metal Bulletin, American Bureau of Metal Statistics Yearbook and Engineering and Mining Journal.

[c] Estimated New York area delivered price from clean No. 2 heavy copper scrap (No. 1 prior to 1956): Metal Statistics and Engineering and Mining Journal.

[d] Major U.S. producer (list) ingot price: Metals Week, Engineering and Mining Journal.

FIGURE VIII-1

TRENDS IN UNITED STATES PRODUCERS' PRICES AND LME PRICES, 1947-1976
(cents per pound)



all of the major foreign producers joined United States producers in selling at essentially the domestic producers' price[16]. Between April, 1966, and late 1970, during the third two-price system, the major foreign producers returned to selling at the LME price[17], while United States producers continued to sell at the domestic producers' price.

- Late 1970-early 1973: A period of slack demand and declining or fluctuating prices in which LME price quotations were generally below the producers' price. United States price controls on refined copper were instituted in August, 1971, but the producers price remained below the established price ceiling until April, 1973.
- Early 1973-Late 1974: A period of great instability in world copper markets characterized initially by a sharp increase in world demand and prices and ultimately by a similarly sharp decline in both demand and prices. Some increase in the producers' price was permitted by the United States government in December 1973; price ceilings were formally abolished in May, 1974. Controls on the domestic producers' price remained in effect through April, 1974.

2. Basic Factors Influencing Prices

As we have seen, demand for copper is quite inelastic in the short-run, and the supply of copper is basically slow, characterized by long adjustment periods. Hence, wide swings in demand over the business cycle in industrial countries, combined with speculative activity in the very short-run on the two organized commodity exchanges, have contributed to the volatility of copper prices internationally. As we just pointed out, however, United States domestic producers' prices, while lagging LME prices, have generally been considerably more stable.

The relationship between the LME prices and the United States producers' prices has been the subject of widespread discussion but very little illuminating analysis, as we shall explain in some detail below, with reference to the "two-price system". For now, it may suffice to indicate broadly that primary copper producers' domestic pricing decisions are influenced by a large number of factors, including their production costs, aggregate macroeconomic activity level affecting demand as well as the price elasticity of demand for copper, level of capacity utilization, inventory stocks, the difference between the current and recent LME Prices and producers' prices, their desired rate of return on investment, the possible response by other major producers to a price change, the United States government's stockpiling policies and possible responses to a price change, and the effect of a price change on short-run and long-run substitution of alternative materials for copper (basically substitution away from copper by aluminum). Although all producers may not perceive these factors in the same way or consider them, implicitly or explicitly, with equal weight, they nevertheless can be expected to take some or all of these factors into account in their pricing decisions.

Generally speaking, the domestic primary producers, in response to persistent demand shifts, have tended to change their prices only slowly and not by the magnitude often experienced by the LME price, such that the producers' prices have generally remained well below LME prices during periods of strong-demand and above LME prices during periods of weak-demand. The ability of the domestic primary producers to refrain from following LME prices right to the peak of the upswing and to hold their prices somewhat above the LME prices at the bottom of its downswing has led some to conclude that (internationally) the copper industry "represents a composite picture of competition and collusive restraint"[18]. Such observations, as we shall see, pertain to the reasons for the existence of the "two-price system" and, taken by themselves, provide quite incomplete explanations of the pricing behavior of the domestic primary producers.

Although the primary producers appear to possess discretionary pricing power as is implicit in the existence of the two-price system, there is no evidence to indicate that they have even remotely approached monopolistic pricing. The threat of long-run substitution from aluminum, some competition from secondary producers, the apprehension that domestic customers might shift to overseas suppliers if the domestic producers' price remained above the LME price over a prolonged period, the presence of United States government stockpiles and the threat of government intervention appear to have had substantial downward influence on the pricing decisions of the domestic primary producers.

The threat from overseas suppliers has more recently been perceived in terms of the political commitment on the part of the copper producing developing countries, where copper production has recently been nationalized, to maintain high levels of production and employment. This is widely believed to put downward pressure on prices and thus lead to increasing competition from abroad. Such a perception largely discounts, of course, any possibility of cartelization of copper internationally and/or the likely emergence of an international copper price stabilization program.

United States government policies, in addition, have periodically had a significant effect on the price of copper, especially during "demand crunch" periods, through such measures as export controls and the use of the stockpile. In the 1950's, when the stockpile was being purchased, the increased demand, along with the demand resulting from the Korean War, caused producers to greatly overexpand their capacity, which was later to prove quite costly to them in the late 1950's when, with a severe drop in demand, they were faced with sizeable idle capacity. When prices rose in late 1959, sales from the stockpile were used to keep the price down. In 1965, when copper producers proposed raising their price by two cents per pound at the same time that the LME price was rising fast, President Johnson reacted by threatening to have 200,000 tons of copper sold from the United States strategic stockpile and forced producers to rescind their price increase. Later, the United States stockpile undoubtedly prevented copper prices from increasing beyond the high levels attained during the Vietnam War. Finally, following the unprecedented surge in copper prices (as well as in the prices of other nonfuel primary producers) in 1973, President Nixon ordered the complete disposal of the national stockpile to stabilize copper prices. Copper from the stockpile was then sold at prices considerably above the producers' price, at a time when the producers' price was fixed by government price controls[19].

3. Factors Influencing Sharp Price Increases in 1973-1974

A review of copper price movements and the factors influencing them would be incomplete without a quick glimpse of the factors influencing the extraordinary price increases in 1973-1974. It will be recalled that copper price increases in 1973-1974 was part of a more general "commodity boom" affecting nonfuel primary commodities at a time when OPEC oil prices were quadrupled. The sharp rise in copper prices and in commodity prices in general startled most observers and fed fears of impending commodity shortages. The price increases also came at a time of heightened concern about worldwide inflation.

In retrospect, a number of factors appear to have been juxtaposed during this period, each reinforcing the others, in bringing about the surge in copper prices, especially copper prices on the LME. First, on the demand side, simultaneous economic growth in many industrial countries caused a significant shift in demand for copper, coming soon after the recession of 1970-1971. The fact that demand rose simultaneously in most of the industrialized countries meant that when supplies became tight in the United States, this country could not relieve the pinch, as it sometimes had done in the past, with relatively cheap imports. If imports were to be a safety valve, they were going to be expensive[20].

Meanwhile, on the supply side, quite apart from relative supply inelasticity in the short-run, world copper supply became constrained by strikes and political unrest. The supply of copper was affected, for example, by the strikes and political unrest in Chile, a major exporter of copper; and Zambia halted its copper shipments through Rhodesia. In addition, some have blamed the recession of 1970-1971 and the subsequent rise in environmentalist pressures for the failure of sufficient investment for productive capacity expansion in the United States to match the upward shift in demand[21]. The fact that the cost of meeting environmental regulations would be likely to divert some funds away from capital expansion should have been evident, but seems to have been underrated[22]. Further, price controls complicated both investment and production decisions in the early 1970's[23].

These factors were further complicated and exacerbated by the sudden emergence of a "shortage mentality", not solely confined to the United States, which was largely characterized by widespread speculation. This was brought about by fears of supply cutbacks, inflationary expectations and considerable uncertainty surrounding exchange rates. Speculation led to anticipatory buying and in a general building of inventories which in turn fueled the price boom[24].

4. Long-Run Prices and Costs

It is important to note that the costs of production provide, over long-run, a rising floor on prices as discussed in Chapter VI. To recapitulate, Herfindahl had advanced the hypothesis that that long-run price of copper tends to equal the price that is sufficient to induce continued investment at all stages of production, from exploration to refining[25]. This price, which may be regarded as the long-run economic cost of copper production was found by Herfindahl to have remained fairly steady over a long period from 1885 to 1957, after eliminating selected abnormal years and except for the years immediately following World War I when the equilibrium real price (cost) of copper declined as a consequence of changes in mining and processing of copper. More recent evidence appears to indicate that at least until the early 1970's, Herfindahl's hypothesis has held up rather well. However, since about 1973 it is quite likely, based on still incomplete evidence, that there has been a sharp increase in the equilibrium price of copper, perhaps mostly as a consequence of an increase in the real cost of inputs rather than as a result of a deterioration of world copper resources (i.e., ore grade) occurring at a faster rate than increases in total factor productivity[26]. In the United States, an escalation in production costs in real terms, combined with stagnant or negative trends in labor productivity may suggest that the United States copper industry has begun to operate along the sharply rising segment of the industry's long-run average total cost curve.

D. THE TWO-PRICE SYSTEM AND PRICING BEHAVIOR OF THE PRIMARY PRODUCERS

With respect to the pricing behavior of the primary United States and foreign producers, probably the most significant characteristic of postwar copper markets has been the existence in nine of the 27 years between 1947-1974 of a two-price system for refined copper, characterized by a wide divergence between (1) the outside market price for refined copper as represented by the LME price and (2) the price at which domestic United States producers and some of the major foreign producers sold their output. Over this period some or all of the major copper producers held their price below the level that would have cleared the market during periods of rising or excess demand for refined copper and rationed their "available supplies"[27] to customers rather than raise the prices. As noted earlier in Section C, there were actually three two-price systems in effect during three different periods: (1) from November, 1954 to July, 1956; (2) from January, 1964 to March, 1966; and (3) from April, 1966 to early 1970.

The various periods are distinguished principally in terms of differences in who among the foreign producers participated along with the United States producers. During periods when the two-price system was not in effect, either a general equilibrium existed between the LME price and the domestic producers' price, or government controls were in effect on either one or both prices, or they were both subject to the depressing effects of an economic recession. These three periods are discussed below in greater detail than presented earlier:

1. The First Two-Price System (November, 1954-July, 1956)

The first two-price system was set off by a sudden increase in world copper demand at the end of 1954. Between October, 1954 and April, 1955, the LME price ranged from 4¢ to 11¢ above the domestic producers' price. Although United States producers raised their price twice, in January, 1955, and again in March, rationing by the producers during these months was reported in the trade press as the LME price still remained 5¢/lb. above the producers' price in April.

Then, in May, 1955, RST initiated what has been frequently called in Europe the first "producers' price experiment", when it announced that it would sell refined copper at a price approximately in balance with the then prevailing domestic producers' price--about 10¢/lb. below the existing LME price. The announced purposes of this policy were to stabilize the price of copper and keep the price low enough to prevent long-term substitution away from copper.

During this period, Noranda adopted the policy of selling in the United States at the domestic producers' price and abroad at the LME price. All of the other major foreign producers continued to sell directly or indirectly on the basis of LME prices. Although the producers' price was subsequently increased somewhat, the price differential continued until mid-1956, when declining demand for copper led to a rapid decline in the LME price which eventually undercut the producers' price. In October, 1957, RST returned to its earlier policy of selling at the LME spot price on the date of delivery.

2. Slack Demand and Support of the LME (July, 1956-January, 1964)

The demand for copper both worldwide and in the United States was generally slack during the 1957-1964 period. In the recession year of 1958, both the LME price and the producers' price were lower than they had been in nearly a decade. Although demand increased somewhat in 1959 and again in early 1960, producers continued to operate at substantially below capacity.

Most notable between late 1961 and mid-1963 was an attempt by two of the African producers, RST and AAC, to prevent the LME price from slipping below equilibrium with the producers' price by cutting back on production and shipments. The result was, in effect, a single, stable world price for copper, as UMdHK and the Canadian producers continued to sell at the supported LME price.

3. The Second and Third Two-Price Systems (January, 1964-Late, 1970)

The second two-price system developed in January, 1964 in response to a sudden, unanticipated surge in worldwide copper demand which led to a sharp rise in LME prices. The two Zambian producers--AAC and RST--had insufficient inventories to alleviate upward demand pressures. Rather than following the upward LME prices, AAC and RST initiated what came to be known as the second "producers' price experiment". Both the United States and the Zambian producers began selling to their customers at a price well below the world free market price and rationing their output. UMdHK, INCO, and Noranda adopted the Zambian producers' price[28]. Excluding tariff and transport differentials, the major producers thus continued to sell at essentially a common world producers' price during the January, 1964 to March, 1966 period.

This second two-price system or "producers' price experiment" was seriously weakened by pressure from the Chilean government on Anaconda and Kennecott to increase the price at which they sold copper refined from blister imported from Chile[29]. The Chilean government was anxious to maximize short-term revenues in a period of expanding world copper demand. Following several smaller increases, the second two-price system collapsed in early April, 1966, when Anaconda and Kennecott were forced to increase the price of their Chilean copper from 42¢/lb. to 62¢/lb. (the monthly average LME spot price in April, 1966 was 86¢/lb.). The foreign producers refused to follow this increase, AAC, RST, INCO, and Noranda began selling at the LME three months forward price on the date of delivery, while UMdHK resumed its traditional policy of selling at an announced price which closely followed the LME price.

A third two-price system maintained only by the United States producers in the United States market was in effect more or less continuously from April, 1966 until late, 1970. During this period, Noranda sold at the LME price until August, 1968; thereafter it sold in the United States at the domestic producers' price and abroad at the LME price.

The third two-price system was interrupted by a strike in the domestic copper industry from August, 1967 to April, 1968. During much of this period, the domestic producers' price was suspended. Demand reportedly fell off early in 1967 because fabricators had already accumulated very large inventories in anticipation of the strike. At other times, however, demand for copper remained excessive, as reflected by the wide differential between the LME price and the price at which domestic fabricators were obtaining rationed supplies.

4. The Two-Price System Since 1970

Since 1970, domestic producers' prices have generally remained above the LME price, except for 1973 and 1974. LME prices fell off dramatically in 1970, 1971 and 1972 as refined copper supplies exceeded consumption for the first time since 1964. This was a delayed response to the recessionary trends simultaneously in several of the developed nations in 1970-1971. The two-year period covering 1973 and 1974, characterized by "demand-crunch", could be identified as another case of the two-price system; however, it must be kept in mind that the 27-month price control program (October 1971-December 1973) was in part responsible for keeping United States domestic producers' prices below the LME prices, although the producers' price remained below the effective price ceiling. Prices of the United States primary producers remained effectively under government control until May, 1974; thereafter, producers increased their prices only to be met by a plummeting LME price which forced down the domestic producers' price.

In 1975 and 1976, copper prices have followed a generally upward trend marked by a seesaw pattern, in direct response to the pace of worldwide economic recovery from the worst recession of the postwar period. During these two years, United States domestic producers' prices have remained generally above the LME prices, in a market environment characterized by slow economic recovery, a sizeable build-up of refined copper stocks estimated at about two million short tons (May 1977) and the expectation of a strike as the United States copper industry faces labor negotiations at the end of June, 1977[30].

E. EXPLANATIONS FOR THE TWO-PRICE SYSTEM

At least on the surface, the pricing behavior of the major copper producers during periods of excess demand and high LME copper prices seems totally inconsistent with the motive of profit maximization. The major producers themselves have revealed little in detail about their motives other than the common rationale of the fear of long-run substitution for copper by end-users if copper prices are allowed to rise too high or are too volatile.

There appears to be no complete, simple, logical explanation or set of explanations for the rationing behavior of the principal United States and foreign producers during periods of excess demand and hence of the two-price system. All of the available explanations are either logically inconsistent and/or are unable to explain certain "anomalous" behavior on the part of the producers.

We would first like to quickly review the policy concern shown by the United States Government in the past with respect to the whole questions of rationing and the two-price system, in order to put this matter in a policy context, and, second, to examine the various explanations given for the two-price system.

1. The Policy Content

The issue of rationing or "dual distribution" by the major copper producers has been the subject of widespread public interest and policy concern, starting especially with the "Dual Distribution" hearings before Congress in 1965[31]. In January, 1970, the President directed the Cabinet Committee on Economic Policy to make a study of the United States copper market. The Subcommittee on Copper issued its report on May 13, 1970 (known as the Houthakker Report[33]). Although the report deplored the existence of inequities and economic inefficiencies resulting from the two-price system, it did not recommend any government action to force a change in the industry's sales practices. The report subsequently led to the introduction of a bill in Congress (H.R. 17656, 91st. Congress, 2nd. Session) designed "To amend the Federal Trade Commission Act to prohibit certain unfair sales practices in the copper industry". This bill would declare it to be an unfair method of competition and thus a violation of Section 5 of the Federal Trade Commission Act, 15. U.S.C. Section 45(a), to sell refined copper at a price determined by the Commission to be significantly below the world market price unless the seller allocates refined copper among domestic users in a manner the Federal Trade Commission determines is fair and equitable[33]. The objective of the bill was, hence, to ameliorate the alleged economic disadvantage experienced by non-integrated fabricators who must either buy at a higher world market price or prevail upon the domestic integrated producer-fabricator(s) to allocate lower priced domestically produced copper to them[34].

We should finally mention, in this context, that the two-price system has been the subject of an important antitrust suit which has been in progress over the past several years, involving Triangle Industries, Inc., et. al. and several domestic primary copper producers, being litigated in the United States District Court, Southern District of New York.

2. Explanation of the Two-Price System

We will briefly review the explanations of the two-price system offered by the Houthakker report and by McNicol[35], who has performed perhaps the most exhaustive (yet inconclusive) examination of the subject.

a. The Houthakker Report

The Houthakker report described a de facto allocation system in effect during the second and third two-price systems based on two general principles. First, all of the producers reportedly used some historical supply pattern from the period 1961-1963 as the basis for determining allocations: customers as of that period were to be retained, if possible. In addition, however, producers reported that they made additions to and deletions from this base list on the basis of "the long-run interests of the firm". This second principle obviously left producers a great deal of room for altering historical supply relationships when it was considered necessary or desirable to do so.

Thus, the Subcommittee found through direct communication with semi-fabricators that, although a general correlation did exist between the pattern of allocation and the pattern of supply during the 1961-1963 period, at times significant changes had occurred as well. Some customers received only 40 percent of their refined copper needs from the major producers, whereas earlier they had met 75-80 percent of their needs through producer copper. Other firms found their allocations sharply increased[36].

The Houthakker report cited three principal explanations advanced by the industry for the second and third two-price system.

In the first explanation, some industry sources argued that the persistent post-1964 gap between the LME price and the domestic producers' price was simply a matter of delayed recognition of a long-run secular rise in the equilibrium copper price on the part of producers used to ignoring short-run demand fluctuations. Producers were, in effect, continually trying to catch up with what looked like a short-run increase in the LME price during this period.

The second and third explanations were justifications for rationing on the basis that high and volatile outside market prices were nonreflective of actual long-term trends in demand, but were rather caused by strikes, government intervention, and other short-run pressures on the market. Following the LME price under these circumstances would have invited unjustified substitution away from copper[37].

b. McNicol's Explanations[27,35]

David McNicol, in his study of the two-price system, argues that in the face of a sudden unanticipated surge in demand for the refined copper, producers have three alternatives:

- They can choke off demand by letting refined copper prices rise freely, in the process stimulating LRS (and, by implication, a loss of long-run profits);
- They can maintain the price at a level below which they believe it will stimulate LRS and still continue to supply the entire market demand by stepping up output; or
- They can maintain the price at a level below that which will stimulate LRS and ration their production at existing levels, at the same time expanding long-run capacity to bring down the equilibrium price level[38].

Each of these alternatives presents the producers with a basic dilemma: no matter which alternative policy they adopt in the face of a sudden unanticipated increase in demand, the economics of the industry dictate that they may suffer negative consequences.

McNicol immediately rejects the "rudimentary" long-run substitution (LRS) theory as an explanation of the rationing behavior of the primary producers, and hence of the two-price system, by arguing that rationing would not prevent long-run substitution[39]. However, this objection to the LRS theory holds only if we suppose a unified market for copper, since, then, the LRS motive as such makes no distinction among the producers and/or the consumers and so does not provide a forceful explanation of why some producers rationed at times when others did not and why some consumers were rationed at times while others were not. The objection does not apply if the market for copper can be segmented and there is LRS in demand in some markets and not in others.

Hence, the LRS theory cannot be immediately rejected on an a priori basis; its evaluation must rest on its implications. While the LRS theory does not lend itself to statistical testing, it implies that only those markets in which there is not LRS will be rationed (i.e., selective rationing). In other words, if producers were to ration brass mills while continuing to supply most, if not all, of the needs of wire mills, producers could continue to produce at the same level of output, while avoiding both LRS and the need to operate in the short-run at a loss or near loss.

McNicol then proceeds to indicate that domestic brass mills were, indeed, rationed and wire mills not rationed during the first two-price system (1955-1956) and during the first half of the second two-price system (1964-mid-1965). Unfortunately, the same evidence forces him to conclude that domestic wire mills were rationed along with brass mills through the second half of the second two-price system (mid-1965 to 1966) and throughout the third two-price system (1966-1970). This leads McNicol to conclude that the "selective rationing" version of the LRS theory does not provide a satisfactory explanation of the two price system.

McNicol then proceeds to resolve this apparent impasse by following the clues in the trade press suggesting that rationing is more profitable for the partially integrated producers than for the nonintegrated producers. This leads him to his "quantity discrimination" (QD) hypothesis to explain the rationing behavior of some domestic producers and, hence, the two-price system. This hypothesis is based on the observation that all of the United States producers and some of the foreign producers are partially integrated, possessing their own captive semifabricating subsidiaries, for the most part, in the form of wire mills.

McNicol argues that during periods of rising or high demand, semi-integrated producers would have found it possible to increase their profits at the semifabrication stage by cutting back on the total quantity of refined copper they would supply to both their own subsidiaries and to independent fabricators. In essence, the semi-integrated producers would be acting as a monopolist to regulate the availability of supplies and thereby the market prices at which semifabricated goods were sold. Hence, while a producers' costs of refining copper inputs to fabrication would remain the same, the increased selling price of its subsidiary's semifabricated output would provide it with an increased profit margin. It should be noted, of course, that this profit gain would be obtained at the possible expense of LRS among wire mill customers, who might be stimulated to switch to alternative materials because of the increased price of wire mill products.

Hence, McNicol's "story" of the broad features of the two price system in terms of the QD and LRS motives is as follows[42]. Rationing would not be expected to occur during periods of slack demand. In a demand-crunch situation, rationing for the QD motive becomes more profitable and rationing for the LRS motive might be profitable for the nonintegrated producers. Specifically, McNicol's two important hypotheses are: (1) that it was profitable for the integrated producers to ration during the two price systems but not at other times; and (2) that it was profitable for the nonintegrated producers to ration only during the second two price system. He further hypothesizes, while providing no evidence, that it was not profitable for the integrated producers to ration wire mills in 1955-1956 and 1964-1965, but was profitable to ration them during 1965-1970.

The underlying weaknesses of both the revised LRS explanation and the QD explanation for rationing lies in the difficulty of obtaining or developing quantitative data to support these hypotheses. In terms of the LRS motive, as McNicol himself points out, it is almost impossible to accurately estimate, for any one point in time, the price at which copper end-users will begin switching to alternative materials. To assume that producers themselves based their pricing behavior on any more perfect knowledge of potential behavior on the part of copper end-users may be misleading. In addition, the revised LRS explanation ignores a multitude of non-price factors, such as institutional rigidities, expectations of technological change, and the like, which may be reasonably expected to have exerted an important influence on LRS decisions.

In terms of the QD motive, it is similarly impossible to accurately estimate at just what combination of copper prices, long-run demand elasticity in fabricator markets, and producer marginal cost schedule producers would have faced a situation where they could gain more profit from practicing quantity discrimination than they would lose from LRS as the price of copper rose or remained relatively high.

This basic lack of empirical support in McNicol's work leaves a number of questions unanswered. For example, since rationing for the QD motive has a stimulative effect on LRS (by forcing up copper prices or maintaining them at a high level), accepting the QD motive for rationing requires accepting the idea that after 1965 producers felt that they would gain greater profits by rationing wire mills as well as brass mills than they would lose through LRS for wire mill products. But, if this was the case, why did producers not ration wire mills prior to 1965? Did their perception of long-run demand elasticity change? Were they proceeding on a trial-and-error basis? Questions such as these cannot be satisfactorily answered given present information[43].

Further, McNicol's combined QD-LRS theory fails to account for the irregular pattern of participation by the major foreign producers during these periods. AAC, INCO, and UMdHK rationed during the second two-price system between 1964 and 1966, but not during the first and third. The non-integrated nature of these firms means that they would not have rationed for the QD motive. However, if they did ration during the second two-price system for the LRS motive, why not during the first and third? McNicol suggests that because producers do not have identical costs and do not sell in precisely the same markets, rationing might have been profitable at times for some of the major producers while not profitable for others. In other words, these three producers might have been faced with less of a threat of long-run substitution in their European markets or might have been better able to expand production levels in the short-run without a corresponding loss of short-run profits. But this line of reasoning is, once again, primarily conjectural, with little firm evidence offered to support it[44]. RST and Noranda, on the other hand, are both partially-integrated firms which would have had both the LRS and QD motives for participating. While both participated in the first and second two-price systems, RST failed to participate in the third two-price system after 1966[45].

In conclusion, McNicol's QD-LRS theory can, in practice, be evaluated only on an a priori basis; his hypotheses can, in principle, be tested by computing the profitability of rationing using estimated cost and demand functions. But this would be very difficult and McNicol offers no such empirical tests. Consequently, McNicol's explanations remain largely conjectural and inconclusive.

CHAPTER VIII

NOTES

1. Ferdinand E. Banks, The World Copper Market: An Economic Analysis (Cambridge, Massachusetts: Ballinger Publishing Company, 1974) p. 41.

2. Cerro-Marmon Corporation as of February 24, 1976, created by a combination of Cerro Corporation and The Marmon Group, Inc. (Michigan).

3. On this point it is interesting to note that some producers, before 1961, reserved a portion of their output for sales to merchants. These transactions were later largely terminated (mostly at the insistence of the copper companies operating in Africa) on the grounds that sales of this type contributed to destabilizing the market, and many producers inserted "no resale" clauses in their contracts. It is probably true that similar no resale clauses are still employed by many American producers (see Banks, op. cit., p. 43).

4. The domestic producers' price was quoted as delivered Connecticut Valley until July, 1950. Kennecott thereafter quoted its price as delivered anywhere within the continental United States; the other major producers did not follow suit until January, 1954.

5. Prior to 1971, the "E/MJ domestic refinery price" represented a weighted average of the United States producers' price getting more than 97.5 percent of the weight.

6. Metal Statistics 1976--The Purchasing Guide of the Metal Industries (New York: American Metal Market Fairchild Publications, Inc., 1976), p. 65.

7. Ibid.

8. The discussion presented here draws upon the following principal sources: (a) Raymond F. Mikesell, "The Nature of the World Market for Copper", unpublished paper (Eugene, Oregon: University of Oregon, June, 1974); (b) Ferdinand E. Banks, The World Copper Market: An Economic Analysis (Cambridge, Massachusetts: Ballinger Publishing Company, 1974), pp. 41-49; (c) Charles River Associates, Inc. (CRA), Economic Analysis of the Copper Industry (March, 1970), Chapters 5 and 6; (d) Sir Ronald Prain, Copper: The Anatomy of an Industry (London: Mining Journal Books, Limited, 1975), Chapters 7 and 8.

9. LME permits trading in electrolytic wirebars, cathodes, and fire refined ingot or ingot bars. High conductivity fire refined (HCFR) wirebar may be delivered for electrolytic wirebars at a

discount, but, with this exception, substitutions are not permitted.

10. This differs from the COMEX where the Clearing Association has responsibility for honoring transactions. See "Exclusive Interview: Robert Gibson-Jarvie, Executive Secretary of the LME", Metals Week (April 11, 1977), pp. 9-10.

11. See "Exclusive Interview: Robert Gibson-Jarvie, Executive Secretary of the LME", Metals Week (April 11, 1977), pp. 9-10.

The LME price quotes daily may reflect business done in what are usually only small tonnages of copper. Yet these same quotations are used as a basis for pricing infinitely greater quantities of metal which are sold directly by producers to fabricators outside the Exchange. In other words, producers and fabricators use the LME quotations in much the same way as one might use an official stock exchange quotation for a private share deal, and the transaction in no way represents physical copper actually being dealt in across the floor of the Exchange. (See Prain, op. cit., p. 95).

12. The African producers have departed from the policy of selling at the LME price on two occasions. First, during the period 1955-1957, RST sold at announced producer prices, while AAC, UMdHK, the Canadian producers and Chile sold at a common producers' price.

In the period 1964-1966 RST and AAC sold at a common producer price. Union Miniere, the other major African producer, sold at an announced price. In 1958, Sir Ronald L. Prain stated that the UMdHK price followed the Metals Week weighted average export refinery price more closely than the LME Price (see Sir Ronald L. Prain, "Copper Pricing Systems"; address to the Organization for European Economic Co-operation, Paris, June 25, 1958, reprinted in, Selected Papers of Sir Ronald Linsay Prain, Volume II [London: B. T. Batsford], p.15).

Furthermore, during the two years prior to the "second producers' price experiment" AAC and RST had supported the LME price at a fixed level. These periods are discussed in more detail below. The Korean War must also be excluded here, as in this period the maximum domestic producers' price was set by the government (see Charles River Associates, [CRA], op. cit., p. 122).

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13. Trading on the COMEX is done by floor brokers working in a ring through bid and offer procedures daily from 9:45 a.m. to 1:10 p.m. At the end of the day purchases and sales on the COMEX are "cleared" through the Clearing Assocation copposed of commission houses and trading firms. The Association guarantees fulfillment of all contracts handled by its members. This procedure differs from that of the LME which is a market of "principals" (i.e., the participating brokers underwrite the performance of each contract).

    All members of the Clearing Association maintain guarantee funds and fixed original margins within the Association. Trading takes place for delivery in seven specified months--January, March, May, July, September, October and December.

    Delivery on COMEX contracts may be made on any day during these months, at the seller's option, to any registered COMEX warehouse. Warehouses are located in Chicago, St. Louis, and Franklin Park in Illinois; El Paso, Texas; Reading, Pennsylvania; New York City; and Tacoma, Washington. A semifabricator who purchased a contract on COMEX might receive fire refined copper in Tacoma on May 31, while it wanted electrolytic wirebars in New York on May 1.

14. Dealers' buying price for #1 heavy copper scrap prior to 1956.

15. See Banks, op. cit., pp. 41-43.

16. Foreign copper was sold at a slight premium (generally 1.5¢/lb.) reflecting United States tariff and transportation charges.

17. Noranda had returned to selling within the United States at the domestic producers' price in 1968.

18. See B. R. Stewardson, "The Nature of Competition in the World Market for Refined Copper", The Economic Record, 46 (1970), p. 181.

19. See Simon D. Strauss, "Government and Mineral Markets", presentation before the American Metal Market's London Metal Forum, London, England (October 27, 1976).

20. National Commission on Supplies and Shortages, Government and the Nation's Resources, Report of the National Commission on Supplies and Shortages submitted to the President and Congress of the United States (December, 1976), p. 51.

21. For this and some of the earlier points see Richard N. Cooper and Robert Z. Lawrence, "The 1972-'75 Commodity Boom", Brooking Papers on Economic Activity, 3 (1975), pp. 671-715.

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22. This is paraphrased from a statement made by National Commission on Supplies and Shortages op. cit., p. 59.

23. Ibid., p. 55.

24. See Cooper and Lawrence, op. cit., pp. 703-706 and Edward R. Fried, "International Trade in Raw Materials: Myths and Realities", Science, Vol. 191, No. 4288 (20 February 1976), p. 642.

25. Orris C. Herfindahl, Copper Costs and Prices: 1870-1957 (Baltimore: Resources for the Future by Johns Hopkins Press, 1959).

26. See Raymond F. Mikesell, "A Note on Orris Herfindahl's Hypotheses Regarding the Long-Run Price of Copper from the Vantage Point of 1975", preliminary draft (November, 1975).

27. David L. McNicol, "The Two Price System in the Copper Industry", Bell Journal of Economics, Vol. 6, No. 1 (Spring, 1975), p. 50. Also see his "The Two Price Systems in the Copper Industry"; an unpublished Ph.D. Thesis, Massachusetts Institute of Technology, February, 1973.

28. Noranda continued to sell in the United States at essentially the domestic producers' price.

29. The bulk of this copper was re-exported for sales on the international market after being refined in the United States.

30. See "Copper Prices Ride a Speculative Seesaw", Business Week (May 16, 1977), pp. 39-40.

31. "Dual Distribution", Hearings before the Subcommittee on Antitrust and Monopoly of the Committee on the Judiciary, United States Senate, September 15, 16 and 17, on S.1842, S.1843 and S.1844 Part 1 (Washington, D. C.: United States Government Printing Office 1966).

32. Report of the Subcommittee on Copper to the Cabinet Committee on Economic Policy (May, 1970). Also see, "Copper Pricing Practices", Hearings before the Subcommittee on Commerce and Finance of the Committee on Interstate and Foreign Commerce, United States House of Representatives, 91st. Congress, 2nd. Session on H.R. 17657, July 20 and 21, 1970 (Washington, D. C.: United States Government Printing Office, 1971), pp. 11-24, plus the press conference of Hendrick Houthakker, pp. 24-29.

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(Continued)

33. "Copper Pricing Practices", (Ibid.), pp. 3-4.

34. Ibid., p. 4.

35. McNicol, op. cit.

36. Evidence concerning allocation procedures during the first two-price system is equally spotty. In the 1964 Federal Court decision requiring Kennecott Copper Corporation to divest itself of Okonite, a wire and cable firm which it had acquired in 1958, the Court found no evidence supporting the Government's contention that Kennecott had favored its own subsidiaries at the expense of its independent customers during the first two-price system and again in a high demand period in 1959. See "Dual Distribution", op. cit., "United States v. Kennecott Copper Corporation," pp. 188-196.

37. Fisher-Cootner-Baily have argued that producers, in addition to fearing long-run substitution, may resist a short-run rise in the producers' price out of fear that independent miners and new entrants to the industry may take the price rise as a signal of a long-run rise in demand in the market. These independents would then open new mines and/or step up production in response to the higher price, leading to a long-run oversupply of copper and depressed prices during a subsequent period of dampened demand. They cite little evidence in support of this hypothesis, however. Fisher-Cootner-Baily, "An Econometric Model of the World Copper Industry", op. cit., p. 573.

38. Short-run production planning in the copper industry is generally done on a five to six months' basis. Orders for semifabricated products are usually placed a month in advance of delivery and the processing of refined copper from mine output typically involves a three-month period.

    Expanding capacity in an existing mine generally requires eighteen months to three years; however, this involves effectively shortening the life of the mine.

    Although there is generally a ten-to-fifteen year lag between the decision to bring a major copper deposit into production and the beginning of production, the major producers typically have one or more mining projects through the "exploration" stage of the development. From that point, the development period is generally the same as that required to expand capacity in an existing mine.

    Thus, for planning purposes, the short run involves at least a period of six to eighteen months from a given date, and possibly as long as three years, while the long run would prevail at some point between eighteen and thirty-six months in the future and would continue into the indefinite future.

39. Producers have, undoubtedly, been aware of this fact, as it has been frequently mentioned by industry observers in the trade press.

40. Whether or not it is ultimately less beneficial depends on the precise cost schedule facing fabricators, as well as the degree of discretionary pricing which fabricators (as opposed to semifabricators) are capable of practicing--two areas which McNicol does not specifically analyze.

41. Briefly, McNicol argues that, given existing conditions in the United States wire mill and brass mill industries, the differential between the price of wire mill products and refined copper and the price of brass mill products and refined copper should remain constant if fabricators are not rationed. On the other hand, if either wire mills or brass mills are rationed, the differential between the prices of their products and that of refined copper should widen, since the marginal price of copper inputs will be the price on the outside market.

McNicol's argument requires that producers' markets be segmented; in other words, that it be impossible for unrationed semifabricators to resell part of their supplies to rationed semifabricators at a price approaching the outside market price. RST and AAC reportedly inserted "no resale" clauses on their sales contracts during the second two-price system; no apparent legal restrictions exist to prevent foreign producers from following this policy. United States producers might face antitrust prosecution if they did the same, but they may have been able to discourage resales by firms in unrationed markets, given their control over the supply of primary copper.

42. See his Bell Journal article (referenced in Footnote 27), pp. 72-73.

43. McNicol hypothesizes that domestic producers may have initially begun rationing wire mills in the autumn of 1965 in response to a foreign producers' price increase which United States producers were not allowed to match because of United States Government pressure to maintain price guidelines then in effect. Although the needs of domestic wire mills were assumedly being met, the price differential between United States and foreign refined copper led to a price differential between United States and foreign wire mill products. Higher wire mill product prices

abroad would have stimulated a significant growth in wire mill product exports from the United States. This, in turn, would have strained the capabilities of United States producers to continue to meet all of the demand of the United States wire mills for refined copper. Rationing would have solved this problem by bidding up the price of United States wire mill products. The problem lies in explaining domestic rationing of wire mills after January, 1966, when United States controls were placed on wire mill product exports.

44. McNicol refers to Fisher-Cootner-Baily's estimates of a much lower European long-run demand elasticity for copper compared with long-run demand elasticity in the United States. As McNicol points out, however, the weakness of this line of argument lies in the absence of barriers dividing the European market from the domestic United States market.

45. McNicol explains this by suggesting that the "Zambianization" of the RST and AAC firms from early 1967 onward might have had an effect on the willingness of the firms to participate, since the government of Zambia was probably concerned with maximizing short-term revenues. However, RST went off the producers' price in April, 1966; and the Zambian Government did not acquire the legal power to regulate the price of Zambian copper until 1968. McNicol cites no other evidence to support the implication that the producers were attempting to placate the Zambian Government in 1966 by shifting back to the producers' price.

IX. ENVIRONMENTAL REGULATIONS

A. INTRODUCTION

In this chapter, we discuss the environmental laws and regulations affecting the copper industry. This description provides the basis for the discussion, in Chapter X, of the cost and capacity consequences of Federal efforts to control pollution.

It should be noted that although the Federal Government retains ultimate authority for ensuring that environmental regulations are enforced, a good deal of the actual enforcement, as well as interpretation of the laws, is undertaken at the state and local levels. In addition, local authorities have considerable latitude in requiring pollution control beyond that needed to meet Federal standards. Therefore, the regulatory framework in which individual copper mining, smelting, and refining operations function varies by state and by local authority within the state. As far as the copper industry is concerned, the significant impacts generally result from Federal standards since most state or regional regulations are not more stringent. An exception is the Puget Sound Air Pollution Control Agency which has adopted regulations that are more stringent than the Federal standards. Even in this case, the Federal Government, through the regional EPA office, has been involved in providing technical assistance and review.

In Section B, we discuss the 1970 and 1977 Amendments to the Clean Air Act including New Source Performance Standards and efforts to prevent significant deterioration. Section C discusses the Federal Water Pollution Control Act of 1972 together with Effluent Guidelines for copper mining, smelting and refining. Section D enumerates other regulations, still in their formative stage, which could have an impact on the copper industry but were not considered in this study.

B. AIR POLLUTION

This section provides a discussion of the Federal efforts to control air pollution. The historical background is discussed first, followed by a detailed discussion of the laws and regulations applicable to the control of air pollution from copper smelters.

1. Legislative and Institutional Background

a. Air Pollution Control Prior to 1970

Prior to 1970, the most important pieces of Federal legislation to deal with stationary source air pollution were:

- the 1955 Air Pollution Control Act;
- the Clean Air Act of 1963; and
- the Air Quality Act of 1967.

The 1955 Air Pollution Control Act authorized, for the first time, a Federal program of research, training, and demonstrations relating to air pollution control. However, primary responsibility for controlling air pollution resided with state and local governments. The 1963 Clean Air Act gave the Federal Government enforcement responsibility for the first time against both inter- and intra-state polluters; however, enforcement procedures against intra-state dischargers were cumbersome, and not uniformly effective.

The 1967 Air Quality Act embodied the concept that air cleanup required a national effort, but it specified that the states should retain primary authority and responsibility for doing so. The Act authorized the Department of Health, Education and Welfare (HEW) to oversee the establishment of state standards for ambient air quality and state implementation plans for achieving those standards. Following the development by HEW of criteria which set forth the relationships of concentrations of specific pollutants in the atmosphere to damages to "health and welfare", states were required within 90 days to file a letter of intent that within six months they would establish standards for ambient air quality. Moreover, within six more months, states had to develop implementation plans for each of the pollutants in the "air-sheds" over which they had jurisdiction. However, HEW was delayed in providing the criteria for pollutants, and states were slow to act once criteria were issued. By 1970, no state had a comprehensive plan of both standards and implementation in effect for any of the pollutants identified by HEW.

b. The 1970 Clean Air Act Amendments

The major problems experienced with air-pollution control legislation until 1970 were related to inadequate regulatory procedures and the lack of specific standards. The Clean Air Act Amendments of 1970 sought to deal with these inadequacies. The existing law was amended to provide for Federal direction in setting standards and established implementation schedules and enforcement mechanisms.

(1) Criteria and Hazardous Pollutants

The principal objective of the 1970 Amendments was to establish and enforce National Ambient Air Quality Standards (NAAQS) for designated (criteria) pollutants. The 1970 Amendments provided for development and enforcement of two kinds of standards for ambient air quality--"primary" standards necessary to protect health, and "secondary" standards desirable to protect welfare, including property and aesthetics. Economic considerations are absent from the setting of NAAQS; the Agency could not trade-off health and economic factors. The stated goal was the achievement of primary standards throughout the nation between 1975 and 1977.

The Amendments also set forth a strategy for attaining this goal. EPA was to establish air quality standards for major classes of pollutants. So far, such standards have been established for particulates, sulfur dioxide (SO_2), hydrocarbons (HC), carbon monoxide (CO), nitrogen dioxide (NO_2), and photochemical oxidants. In addition, EPA is scheduled to propose an ambient lead standard this year. These standards were to be set on the basis of "threshold values" for the designated pollutants representing levels of ambient concentration below which scientific evidence indicated that no damage occurs to human health. Congress directed the EPA to determine these values and then set primary standards based on these values minus "an adequate margin of safety." In addition, secondary standards were also to be designed which would be sufficient to protect public welfare, broadly defined to include "economic values... personal comfort and well being...effects on soils, water, crops, vegetation, man-made materials, animals, wildlife, weather, visibility, and climate, damage to and deterioration of property...." (Section 302h, CAA of 1970).

The Congress did not rely solely upon the establishment of standards for ambient air quality to control pollution. It also gave the EPA power to set specific limits on the emission of certain kinds of "hazardous pollutants", considered to have especially serious health implications and attributable to relatively few source categories.

These hazardous pollutants are exclusive of the criteria pollutants for which national ambient air quality standards exist. The EPA was directed to prepare a list of such substances and to issue regulations limiting their emissions by both new and existing sources, which were to be enforced at the Federal level.

Standards have been set or are in the process of being set for asbestos, beryllium, mercury, vinyl chloride, vanadium, and cadmium. The Amendments allow for two years' (discretionary) lead time for compliance by existing sources with emissions standards for hazardous air pollutants.

(2) Implementation of Ambient Air Quality Standards

The 1970 Clean Air Act Amendments recognized the role of the States, EPA and private groups in implementing the NAAQS.

The states were to exercise primary responsibility for attaining and maintaining ambient standards. The Amendments directed the states to develop State Implementation Plans (SIPs) showing how they would achieve ambient standards by mid-1975. A two-year extension of the deadline was permitted in those regions where the necessary technology was not available when needed to meet the mid-1975 date.

Each Implementation Plan, typically, was a compilation of state air pollution statutes and regulations and of pollution control strategies including emission limitations, land use controls and transportation controls. The states were not bound to enacting technically and economically feasible directives for individual sources. It should be noted, however, that despite the name, these Plans were not mere statements of general intention, but rather were fully enforceable legal documents prescribing how and when individual sources were to comply. EPA's role was to ensure that the SIPs would achieve and maintain NAAQS consistent with the emissions reduction philosophy of the Amendments. In the event that a state did not submit an adequate plan, EPA was responsible for publishing an effective implementation plan. Once approved, a State Implementation Plan could be enforced by the state, Federal Government, or private citizens.

Because different geographical, climatic and other conditions introduce necessary variations in the state plans and because each plant contained several often complex programs, EPA developed a policy of approving them on a program-by-program basis. In most SIPs, considerable emphasis was placed upon the development of source control plans for the achievement of primary standards.

(3) Establishment of National Emission Standards for New Sources

The objective of minimizing emissions of pollutants from new or modified stationary sources was also written into the Clean Air Act Amendments of 1970. The Amendments directed the EPA Administrator to set "New Source Performance Standards" which limit the emission of pollutants from new or modified sources to an amount no greater than that attainable with "the best system of emission reduction which (taking into account the cost of achieving such reduction) the Administrator determines has been adequately demonstrated." The Act specifically provided the EPA Administrator with the option of distinguishing among "classes, types, and sizes" within source categories. In most cases, process units rather than entire plants have thereby been assigned emissions limitations. New Source Performance Standards for copper smelters were published by EPA in January 1976.

(4) Citizen Participation

Allowance for major public participation in the law's execution, both in standard setting and in enforcement, was an additional key feature of the 1970 Amendments. Suits brought by various groups have already had a significant impact on the law's interpretation and implementation. For example, the Natural Resources Defense Council has successfully challenged portions of the State Implementation Plans which permitted the issuing of temporary operating certificates of variances. The Sierra Club and other organizations, in a separate case, succeeded in requiring EPA to adopt regulations concerning significant deterioration of existing air quality.

(5) Issues Arising from the 1970 Clean Air Act Amendments

Validity of Ambient Air Quality Standards

EPA is continuing technical studies to validate the six ambient air quality standards established in 1971. Other pollutants such as fine particulate, sulfate, lead, etc., are being studied extensively by the EPA for possible consideration as criteria pollutants.

Intermittent Versus Permanent Control Systems

A major controversy evolved after passage of the 1970 Amendments over the advantages of permanent control devices (scrubbers) versus the advantages and legality of intermittent control systems for controlling SO_2 emissions. Scrubbers remove sulfur from stack gases after combustion but before emission to the atmosphere. Intermittent control systems seek to disperse stack gas and dilute SO_x emissions by use of tall stacks and various operating practices, including curtailing operations or switching to low sulfur fuels during times of anticipated adverse air quality or other unusual meteorological conditions.

In 1974, the United States Court of Appeals for the Fifth Circuit, in Natural Resources Defense Council vs. EPA, held that intermittent control systems are acceptable only when emission reduction equipment has been used to the maximum extent feasible. In September 1973, EPA proposed that "supplementary control system" (SCS) be permitted as a temporary measure applicable only to sulfur oxide emissions from isolated nonferrous smelters and coal-fired power plants, where the sole alternatives were permanent curtailment of production, closing of the plants, or delays in attainment of the standards. However, constant emission limitation remained the preferred strategy for attaining and maintaining the standards in the long-term. Tall stacks would also have been allowed under the proposal as a part of an approved supplementary control system. This aspect of the 1973 proposal was cited by the Fifth Circuit as an example of EPA's improper reliance on stack height as a means of achieving NAAQS. Subsequently, EPA proposed regulations allowing the interim use of SCS at several smelters located in the Western United States in such states as Arizona, Montana, New Mexico, and Utah. These regulations required the installation of Reasonably Available Emission Control Technology (RACT) and further stated SCS could be employed only if certain conditions outlined in the regulations were met, and its use was needed to achieve national standards.

State Implementation Plans (SIPs)

The 1970 Amendments required the states to submit SIPs for existing stationary sources of "criteria" pollutants that would assure that national primary ambient air standards would not be exceeded in any part of a state after mid-1975 (or after 1977 when a two-year extension was granted). With a few notable exceptions (e.g., sulfur oxide emission limitations in the State of Ohio), all states had fully enforceable emissions limitations affecting stationary sources by 1974, although in portions of 16 states an extension had been granted for one or more pollutants.

State and Federal programs faced an immense task in achieving compliance since there are estimated to be over 200,000 stationary sources subject to SIP emission standards. Of this number, however, approximately 20,000 are major emitters (i.e., facilities individually capable of emitting over 100 tons of a pollutant per year), which as a class, produce about 85 percent of all air pollution emitted by stationary sources. Accordingly, EPA and state enforcement programs focused on ensuring compliance by this class of emitters in order to have the greatest impact on pollution abatement.

In May 1972, the SIPs for the States of Arizona, Idaho, Montana, Nevada, New Mexico, and Utah were disapproved insofar as they applied to nonferrous smelters. Promulgation of Federal replacement regulations were delayed due to controversies over air quality data, the availability of controls and the possible use of intermittent control systems and tall stacks.

Resolutions to these problems were approached in late 1973, and EPA had finalized Federal regulations for the control of SO_x for some primary nonferrous smelters by early 1975. Regulations proposed required the application of the reasonably available retrofit control technology, and, if necessary, allowed the interim use of supplementary control systems (SCS) and tall stacks until adequate constant control techniques became available. Each smelter using SCS was further required to conduct a research and development program to hasten the development of such technology.

The SIPs in some states failed to fully meet EPA requirements, in others, states and local agencies adopted technically impractical standards for existing sources or chose to supersede technically-based EPA standards for new sources in order to control the use of land, for example.

Three separate court cases, involving challenges on the reasonableness of regulations contained in SIPs approved by EPA, resulted in a Supreme Court ruling that the EPA need not consider technical feasibility and economic practicality in approving state-submitted SIP regulations. EPA can deny a SIP if it will not result in the attainment of air quality standards. Under these conditions, EPA must consider availability of technology, economic practicality, etc., in proposing alternative SIPs.

State Variances

Most state implementation plans were drafted so that all emission limitations were effective immediately. Because most sources were not in compliance with emission limitations of implementation plans, there was a transition period (still continuing for some) between the time a plan became effective and the time that ambient air standards had to be attained. The most common way of dealing with source noncompliance was for a state pollution control authority to issue a variance from the requirements, provided that the source and the state reached an acceptable compliance schedule and that the national ambient air quality standards were met by the statutory deadlines. EPA took the position that such variances would be treated as revisions of the state implementation plans, requiring approval by EPA.

This variance procedure was challenged throughout the country and much litigation ensued. In April 1975, the Supreme Court held that the purposes and philosophy of the Clean Air Act of 1967 were not changed by the 1970 Amendments. Accordingly, the chief responsibility for attainment of ambient air standards rested with the states. So long as a state's control strategy achieved and maintained ambient air standards through emissions reduction, the Court ruled that EPA could not interfere with the state's timing or its enforcement techniques unless there were significant delays.

"Significant Deterioration" Controversy

Although the original Clean Air Act of 1970 contained no mention of "significant deterioration" (the words used in the act are "protect and enhance" air quality) in a 1972 suit brought by the Sierra Club against the EPA, the District of Columbia District Court ruled that according to the provisions of the Clean Air Act, no state could permit "significant deterioration" of air quality in areas where it was already cleaner than required by ambient standards. This ruling was upheld by the Supreme Court, and on August 16, 1974, EPA proposed regulations to incorporate the District Court opinion into state implementation plans.

The EPA regulations, covering particulates and SO_2, were published after long public debate about the nature and severity of the controls. Those seeking strong controls had argued that the court ruling required state implementation plans that would fully protect clean air areas from pollution by new industrial facilities. Those favoring less control argued that there must be some provision for growth and industrialization even in clean air areas and that a strict interpretation of "significant deterioration" by EPA would in effect amount to land use controls prohibiting new industrial development.

The proposed final regulations separated areas into three classifications--Class I, where air quality would be protected at existing levels; Class II, where moderate changes would be permitted; and Class III, where major industrialization and growth would be allowed to a point at which air pollution reached national standards. All areas were to be established as Class II areas at first, with authority given state governors to change any to Class I or III. In this way, the Federal Government would not be forced to determine industrial siting policies for regions based on air quality alone but would allow wide discretion to the states. The regulations were adopted in final form by EPA on November 27, 1974.

The regulations were challenged by industry and environmental groups. Industry sought to have the regulations set aside as an arbitrary and capricious exercise of authority. At the same time, the Sierra Club (the successful plaintiff in the original district court suit that forced promulgation of the regulations) and other environmental groups brought legal challenges on two grounds--that the regulations allowing growth and siting of facilities in Class III areas violated the court order and that the Act did not allow limiting the regulation to particulates and SO_x emissions, but required that all criteria pollutants be included.

"Non-Attainment"

EPA's Interpretive Ruling of December 21, 1976, addressed the issue of industrial growth in regions where national air quality standards were not being attained. This ruling provided that a major new source of air pollution could be built in such areas only if a set of specified conditions were met. These conditions required the control of emissions from the new source to the greatest degree possible and a more than equivalent offsetting emission reduction from existing sources (labelled "emission offsets") so that there was progress toward the achievement of standards.

This Ruling defined major sources as those with emission of 100 tons or more per year of each pollutant (1,000 tons for carbon monoxide). EPA simultaneously proposed a tentative definition for major sources based on half the emissions rate mentioned above. These major new sources would have to meet a lowest achievable emission rate, which, at a minimum was the same as the applicable New Source Performance Standards. During the preconstruction review phase of a project to construct such a major new source, the following considerations were to be taken into account to determine the emissions offset.

The emissions offset had to be from a "baseline" State Implementation Plan (SIP) that was considered adequate by EPA and not one that was rejected as being substantially inadequate. Furthermore, there had to be a more than one-for-one emission offset and any leftover emission offset credit could not be "banked" for future pollution growth. Emission offsets could be based on sources owned by the new source owner or by other parties with whom the new source owner was able to arrange for the offset.

c. The Clean Air Act Amendments of 1977[1]

The Clean Air Act Amendments of 1977 were signed into law on August 7, 1977. In general, these Amendments reaffirm the basic goals and strategy of the Clean Air Act of 1970; namely, ambient standards should be achieved via the permanent reduction of emissions. As before, the responsibility and authority for enforcing these standards rests with the state and local bodies. The Amendments, in addition, clear up several of the controversies and ambiguities resulting from the 1970 Amendments, generally by accepting court decisions and EPA's interpretive rulings and policy formulated in the interim. EPA has been provided with new tools to do its job. Finally, the Act allows for special consideration of certain industries in order to avoid undesirable side effects of strict regulation.

(1) Basic Approach

The basic goals and strategy for achieving air pollution control remain unchanged. The Amendments, therefore, rely on the establishment of National Ambient Air Quality Standards designed to protect public health and welfare and emission standards, based on control technology, to reduce pollutant concentrations below the ambient standards and keep them there. The new law also retains the State Implementation Plan as the basic mechanism through which this approach is implemented.

For those areas which have not attained ambient standards, so-called "nonattainment areas", states must have an approved implementation plan revision by July 1, 1979, which provides for attainment of primary standards by December 31, 1982. This requirement is a recondition for construction or modification of major emission sources in nonattainment areas after June 30, 1979. If, despite implementation of all "reasonably available measures", a state cannot attain primary standards for carbon monoxide or photochemical oxidants in timely fashion, it must submit a second plan revision by December 31, 1982, which provides for attainment by December 31, 1987. This flexibility is not available to stationary sources. All plan revisions must, prior to attainment, provide for "reasonable further progress" toward attainment in terms of additional annual reductions in emissions.

For those areas which are cleaner than required by ambient standards, implementation plans must include an elaborate program to prevent the significant deterioration of air quality. All such "nondegradation" areas must be designated Class I, II, or III, depending upon the degree of deterioration that is to be allowed, and limits are assigned to increases in pollution concentrations for each classification. Congress specified which of these areas must be protected by the most stringent Class I designation. All others would be initially designated Class II, with states generally free to redesignate them as Class I or III. Congress also specified the maximum allowable increases in concentrations of sulfur dioxide and particulate for each classification and gave EPA two years to come up with comparable formulas for hydocarbons, carbon monoxide, photochemical oxidants, and nitrogen oxides.

In both "nonattainment" and "nondegradation" areas, major stationary sources may be constructed only by permit and must, at the very least, meet New Source Performance Standards prescribed by the law. As a general rule, these will require application of the "best technological system of continuous emission reduction".

(2) Responsibility and Authority

Congress has prohibited EPA from requiring the inclusion or retention of indirect source review programs and "land-use" controls as a condition of implementation plan approval. It also blocked EPA from imposing such programs in implementation plans which the agency promulgates, except with respect to major Federally funded public works projects such as highways and airports and Federally owned and operated indirect sources.

Any state or local government may adopt or retain indirect source review programs, and EPA may enforce any such measure approved as part of an implementation plan, but the state involved will always be free to suspend or revoke indirect source review at any time.

The states may petition EPA to publish or revise national New Source Performance Standards for sources of pollutants which may have been overlooked or when new technology would dictate a more stringent standard. The purpose of this provision, of course, is to allow any state to adopt stringent standards without fear that an affected company will seek an "air pollution haven" in some other state.

Governors are given new authority to suspend portions of transportation control plans and will have more say in revision of air quality control region boundaries, redesignation of nondegradation areas and other aspects of that program, and certification of coal conversion orders. Governors may also issue extended compliance orders to stationary sources, unless EPA objects for cause and may even temporarily suspend implementation plan provisions in the event of a bona fide energy emergency.

Few restrictions are placed on a state's right to impose more stringent requirements than might be prescribed by EPA, and governors may insist on the use of locally mined coal under certain conditions. All Federal facilities must comply with both substantive and procedural requirements of Federal, state, regional, and local air pollution control laws and regulations.

Local and regional officials must be brought into state decisions regarding transportation controls, preconstruction review, nonattainment, and nondegradation through a "satisfactory process of consultation" which is prescribed in the state implementation plan. Enforcement authority for implementation plans promulgated by EPA may now be delegated to local governments.

(3) Special Considerations

Congress realized that certain portions of the private sector had its problems meeting the 1970 requirements. As a result, several industries were singled out for special consideration including the automobile industry, nonferrous smelters, fossil fuel-fired plants prohibited from burning oil or natural gas, etc. In many instances, Congress reduced the compliance requirements for small installations. In most of the remaining cases, this special consideration was usually a waiver from the time deadlines for compliance and not from the ultimate requirement for compliance.

(4) New Tools for EPA

Amendments to Sections 111 and 112 of the original Act allow EPA to set design, equipment, work practice or operational standards to control emissions of criteria pollutants from new stationary sources and of hazardous emissions from any source. These standards may only be imposed when it is not feasible to establish a more traditional emission standard, and they must be changed to emission standards whenever possible. Alternative methods of emissions reduction which are equally effective may also be used with EPA's approval.

With respect to hazardous pollutants, these standards must be adequate, in EPA's judgment, to protect public health with an "ample margin of safety." For new or modified sources, such standards must reflect the "best technological system of continuous emission reduction" which--taking into account costs, energy requirements, and health and environmental impacts other than air quality--EPA determines to be "adequately demonstrated." Proper operation and maintenance requirements must be included in the standards.

Under Section 113 of the original law, injunctive relief was the only civil remedy a court could impose. The new law authorizes courts to impose civil penalties up to $25,000 per day of violation, taking into account the seriousness of the violation and the economic impact of the fine on the violator.

To limit any abuse of EPA's enforcement powers, Congress allowed courts to award litigation costs to defendants against whom EPA brings a frivolous or otherwise unreasonable action. However, courts would have to find an EPA rule "arbitrary and capricious" before it can be overturned.

Other new regulatory tools include waivers of emission control deadlines for innovative technology for both stationary and mobile sources, and sanctions pertaining to nonattainment of environmental regulations.

Another provision seeks to supplement standard regulatory procedures by bringing public pressure to bear on state and local governments. States must include in their implementation plans effective measures to notify the public when air pollution levels exceed primary standards and to educate the public as to the hazards involved and corrective measures available.

Increased reliance on Presidential authority is also provided where standard regulatory procedures could lead to stalemate--as in settling disputes between governors and Federal land managers over variances for Class I nondegradation areas; regulating radioactive pollutants otherwise governed by energy authorities; disapproving EPA aircraft emission standards found unsafe by the Secretary of Transportation; and declaring an energy emergency so severe as to warrant suspension of state implementation plan requirements.

(5) Shifts in Strategy

Section 405 of the new Act requires EPA, in consultation with the Council of Economic Advisers, to conduct a comprehensive investigation into "economic measures" to supplement existing regulatory authorities, provide incentives for additional emission reductions, and "serve as the primary incentive for controlling air pollution problems not addressed by any provision of the Clean Air Act (or any regulation thereunder)." The overall study is due in two years, but EPA will have only one year to assess the feasibility of establishing an emission charge on oxides of nitrogen from stationary sources. In addition to this study of economic incentives, new Section 120 gives EPA only six months to publish regulations requiring stationary sources to pay "noncompliance penalties" for failure to meet certain emissions standards by July 1, 1979, in most cases. The penalty is designed to assure that no company will profit from delaying control expenditures and thereby obtain a competitive advantage over companies which have installed controls. Penalties are determined by administrative process, based on the cost of compliance, plus any additional economic value resulting from the delay, minus expenditures for interim control expenditures.

Both EPA regulations and specific penalties may be reviewed by the Federal courts, but the noncompliance penalty is in no way the same as a court-imposed fine. In fact, the law explicitly states that noncompliance payments shall be imposed in addition to civil or criminal fines.

Section 129 of the new law ratifies, by statute, the basic EPA "emissions offset" policy. This emissions offset policy represented an "interpretive ruling" on existing law when EPA first formally introduced it in 1976. This policy allows new stationary sources in nonattainment areas only when pollution from existing sources in the area has been reduced to more than compensate for the new emissions. This policy would remain in effect until July 1, 1979, although Congress allowed for exceptions and waivers under certain circumstances. By July 1, 1979, the objectives of EPA's emission offset policy must be incorporated into the state implementation plan process. In effect, no major source may be constructed in a nonattainment area unless combined emissions from existing sources, new minor sources and the proposed major source will be sufficiently less than total emissions from existing sources, as to represent reasonable further progress toward attainment of standards. An alternative formula appears to allow construction of new major sources which do not exceed a maximum allowable increase in emissions, as specified in the implementation plan, and any new major source must comply with the lowest achievable emission rate. The implementation plan itself must provide for attainment of primary standards as soon as possible, but not later than December 31, 1982, for most pollutants, and five years later for carbon monoxide and photochemical oxidant.

2. Specific Federal Provisions Affecting Copper Smelters

The Clean Air Act Amendments of 1970 and 1977 establish four principles that are particularly relevant to air pollution control in copper smelting. They are:

- National Ambient Air Quality Standards[2] must be met at all times by the use of permanent emission reduction technology. Dispersion by any means, most notably by use of tall smoke stacks, and production curtailment (to reduce emissions under adverse meteorological conditions) are not acceptable means of achieving ambient air quality standards;

- All new, reconstructed and modified production equipment must meet New Source Performance Standards. All new sources must employ at least NSPS calibre technology;
- Smelting activity cannot lead to significant deterioration of existing air quality in regions which are cleaner than the ambient standards; and
- In areas which have not attained ambient standards, several preconditions must be met before undertaking the modification of an existing emission source or the construction of a new emission source.

a. Emission Reduction

At the time of the Clean Air Act of 1970 only one of the domestic smelters was able to meet the National Ambient Air Quality Standard for sulfur dioxide without resorting to dispersion and production curtailment techniques (Supplementary Control Systems). Most other smelters were only capturing 17 percent to 40 percent of the sulfur dioxide generated during production, whereas capture rates in excess of 90 percent were typically required to prevent ambient violations.

The cost, economic impact and technical difficulty of immediately achieving the sulfur dioxide standard were viewed by EPA as severe. The Agency developed the Tall Stacks Policy in part to permit, on a temporary basis, the use of Tall Stacks and Supplementary Control Systems (SCS) to achieve ambient standards. The Tall Stacks Policy provided that an existing smelter could utilize tall stacks and SCS to meet ambient standards so long as it employed Reasonably Available Control Technology, and conducted a research and development program leading to eventual attainment of NAAQS through permanent control alone. New smelters could not rely on Tall Stacks or SCS to meet ambient standards.

Reasonably Available Control Technology (RACT) was defined as control of at least all strong sulfur dioxide gases (approximately 4-5 percent SO_2) by a double absorption acid plant, if these gases were not being treated, or control by a single acid plant if such a system were already being utilized.

By comparison to the New Source Performance Standards (discussed below), the Tall Stacks Policy permitted the continued use of uncontrolled sources of weak gas streams (namely, multiple-hearth roasters and reverberatory furnaces) and allowed the use of the lower efficiency single absorption acid plant. Weak gases cannot be treated by the conventional autothermal acid plants used in the industry. To ensure that the pollution control equipment, once installed, was being effectively utilized, a RACT mass emissions limitation (RACT "bubble") was established for each smelter. The RACT emissions limitation was calculated assuming capture of sulfur by the required control equipment at capacity production. Because the RACT emissions limit was calculated at capacity production, this mass emissions limit did not by itself adversely affect the utilization of existing capacity. However, because RACT emissions at capacity production levels were often sufficient to violate NAAQS for sulfur dioxide, the smelters were not able to operate at the RACT mass limit at all times. This meant that the effective capacity of many smelters was reduced. Once established, the RACT emissions limit could not be increased.[3] The policy implied that most smelters were operating under an emissions ceiling that could not increase to accommodate physical or operational changes. Further, the RACT bubble could decrease either because the EPA determined that incremental pollution control equipment was reasonably available or because changes were made to the smelter which made once-and-for-all emissions reductions possible.

The Tall Stacks Policy was ambiguous in defining when (and under what conditions) smelters would be required to attain ambient standards solely by use of constant controls. It also did not address whether an average-sized smelter using NSPS caliber technology could meet ambient standards using permanent controls alone. Finally, the policy did not directly address the role that fugitive emissions might play in NAAQS violations and the means available for preventing these violations.

The Clean Air Act Amendments of 1977 have resolved most of these uncertainties. First, an ultimate emission limitation is established at a level sufficient to ensure NAAQS are met at all times without the use of dispersion techniques or production curtailment. This ultimate emissions limit is to be calculated assuming stack heights of two-and-one-half times building height or less for stacks built after 1970. Generally, this is equivalent to a stack height of about 300 feet. For operational purposes, smelters can employ a stack of any desired height. Thus, the Amendments require the establishment of ultimate sulfur dioxide emissions limitations for every smelter. If a state fails to establish such an ultimate emissions limit in a SIP, EPA is required to do so. These limits are to be met once established, unless the smelter receives a primary nonferrous smelter order (NSO).

The NSO is essentially a five-year variance, renewable once, which allows a smelter to operate using reasonably available control technology together with tall stacks and SCS. Only those copper smelters that are technically or economically unable to meet the ultimate emissions limit for sulfur dioxide are eligible to operate under a NSO. Upon termination of the NSO, the smelter must either be achieving the ultimate emissions limit or close. As a condition of operating under a NSO the smelter must install as much pollution control equipment as it can afford, must continue R&D on emissions reduction technology, and must achieve ambient air quality standards. In addition, the smelter is subject to the RACT emissions limit throughout the period of the NSO. If a smelter cannot afford any sulfur dioxide control (this is claimed to be the case at two smelters) an NSO may still be granted. This is a potentially significant change from the 1970 Amendments which have been interpreted by some courts as requiring some degree of permanent control before temporary measures to meet ambient standards could be allowed.

In short, the Clean Air Act Amendments of 1977 require every domestic smelter to meet ambient standards solely with emissions reduction equipment. This requirement is to be met no later than January 1, 1988. In the interim, EPA is charged with ensuring that all smelters make the fastest economically and technically feasible progress toward meeting the ultimate emission limitations.

b. New Source Performance Standards

New Source Performance Standards (NSPS) refer to regulations applicable to the building of new plants or to major modifications of existing plants. The Clean Air Act Amendments of 1977 do not materially affect the NSPS applicable to copper smelters.[4] The NSPS for copper smelting apply to "facilities" (major pieces of process equipment) and do not directly apply to the source or smelter complex per se. Thus, the standards specify the maximum emissions rates allowed from process equipment. Although the smelter emissions rate consistent with New Source Performance Standards can be deduced from detailed knowledge of the smelter's process equipment, configuration, and charge characteristics, there is no necessary relationship between this emissions rate and the ultimate emissions rate (discussed above) since that limit is based on ambient air quality and not on technology.

The NSPS require that any new, reconstructed or modified smelting furnace, roaster or converter may not emit gases which contain sulfur dioxide in excess of .065 percent (by volume). Essentially this means that the gases from any production facility subject to the standard must be treated by a double absorption acid plant. Alternatively, the standard requires that the pollution control system must remove at least 99.6 percent of the sulfur dioxide generated during the production process. Reverberatory furnaces are exempt from NSPS only during periods when the smelter is processing impure concentrates.

Excepting the single exemption for some reverberatory furnaces (noted above), all new roasters, smelting furnaces, and converters must meet NSPS. This requirement holds for all such facilities regardless of whether the new equipment replaces or augments pre-existing process equipment.

A facility is considered to be reconstructed, and therefore subject to NSPS, if (1) the capital cost of new components exceeds 50 percent of the (fixed) capital cost of a comparable new facility and (2) it is technically and economically feasible to meet the applicable performance standard. The NSPS require smelter owners and operators to notify EPA of any potential reconstruction and to provide detailed information regarding the contemplated action. The Agency is required to determine within 30 days of notification whether the proposed action constitutes a reconstruction.

If a facility is modified, it must meet NSPS. Any physical or operational change to a facility is a modification if (1) emissions from the facility increase and (2) total emissions from the smelter as a whole increase. Both criteria must be met in order for a facility to be modified. For example, if an emissions increase from a smelting furnace were totally offset by an emissions reduction from the converters, the furnace would not be modified and would not, therefore, be subject to NSPS. However, if the emissions increase from the furnace were not offset elsewhere in the smelter, the furnace would be modified.

If a smelter is subject to a RACT emissions limit that cannot be increased (this is or will be the case at most smelters), then the modification provisions have vacuous application. Since such sources cannot increase emissions, there is no way that the modification provisions could independently apply. For these smelters the reconstruction and new construction provisions of NSPS are the only provisions that could result in more stringent control of smelter emissions than the smelter-wide RACT limit.

To date, the modification, reconstruction and new equipment provisions of the NSPS have not forced the upgrading of pollution control equipment at any existing smelter.

c. Prevention of Significant Deterioration

In 1974, EPA promulgated regulations to prevent the significant deterioration (PSD) of air quality in areas where the air is cleaner than is required by the National Ambient Air Quality Standards. (This is approximately 75 percent of the United States' land area.) The EPA regulations affected 19 categories of industrial sources commencing construction or modification after June 1, 1975. Although EPA's specific regulations were upheld by the D.C. Court of Appeals in 1976, the PSD concept has received extensive scrutiny by Congress, and the Clean Air Act Amendments of 1977 include strong PSD provisions.

The PSD provisions contained in the 1977 Amendments are similar to the earlier EPA regulations in that they establish three area classifications designed to correspond to the change in air quality intended for an area. The classifications of air quality levels are based on how much increase (over the air quality as of January 6, 1975) will be permitted in ambient concentrations of particulate matter and sulfur dioxide. The allowable increase in concentration is referred to as an increment. Briefly, the classifications are:

- Class I where practically any air quality deterioration would be considered significant;

- Class II where deterioration in air quality that would normally accompany moderate growth would not be considered significant; and

- Class III where more extensive industrial growth would be accepted. In no event is a source permitted to cause or contribute to air quality levels exceeding the National Ambient Air Quality Standards.

EPA initially designated all areas of the country as Class II, allowing States to redesignate areas, including Federal lands, either Class I (pristine) or Class III (greater economic growth).

The Amended Act differs from the EPA regulations in the sources and pollutants covered, the numeric limits for each class, class designations, control technology requirements, and application and review requirements. The Amendments:

- Cover additional source categories and all sources with the potential to emit more than 250 tons per year.
- Tighten the Class II sulfur dioxide increment and adopt an increment approach to Class III.
- Designate as Class I all International Parks, National Wilderness Areas and National Memorial Parks over 5,000 acres, and all National Parks over 6,000 acres (approximately 130 total areas).
- Authorize the Governor (with the concurrence of the Federal Land Manager) to grant a variance to the Class I increments for up to 18 days per year.
- Require best available control technology for new and modified sources, determined on a case-by-case basis[5] and applicable to all pollutants subject to regulation under the Act.
- Require permit applicants to demonstrate compliance with PSD air quality increments to be preceded by an analysis of existing air quality at the proposed site and to analyze the air quality impacts of growth associated with the applying facility.[6]
- Require public hearings on the air quality impacts of the proposed source, alternatives thereto, and control technology requirements.

In November 1977, EPA proposed revisions to the PSD regulations to reflect the requirements of the 1977 Amendments. The EPA regulations serve as a guideline to the States and apply to all sources commencing construction prior to approval of a State PSD program.

Associated with PSD measures in the Act is a provision to protect visibility in Federal Class I areas. This section of the 1977 Amendments directs EPA to develop regulations to prevent any future (and to remedy any existing) impairment of visibility in mandatory Class I areas. The visibility requirements apply to any source which began operating in the past fifteen years and may require retrofit with the best available control equipment. The EPA regulations are to be developed in consultation with the Department of Interior and the States and are to be published by August 1979.

d. Nonattainment

Parts of the country which have not achieved ambient air quality are the nonattainment areas. An area may be shown to be a nonattainment area by monitored air quality data or by air quality modeling. Since most existing copper smelters are not at the ultimate emissions limit but are using RACT and SCS to achieve ambient air quality, the areas in which these smelters are located will be designated nonattainment areas with respect to sulfur dioxide emissions.

The 1977 Amendments require SIP revisions (by July 1, 1979) which would provide for the attainment of primary standards by December 31, 1982. This SIP revision is a precondition for the construction or modification of major emission sources in nonattainment areas after June 30, 1979. The Amendments require such a SIP to provide for annual incremental reductions in emissions via the adoption, as a minimum, of RACT as expeditiously as possible. The SIPs must also contain a comprehensive emissions inventory for existing sources and proposed new sources. They must also contain emission limitations and compliance schedules.

The construction and operation of a new or modified emission source will require a permit. Prior to the issuance of such a permit, it is necessary to conduct an analysis of alternative sites, sizes, processes and environmental control techniques.

The "emissions offset" policy also applies so that total emissions in a region after the construction or modification of a facility must be lower than the prior emissions so that there is reasonable progress towards the attainment of standards. Alternately, if the construction of a new or modified source results in a net increase in emissions, this increase has to be within the allowance permitted for such a pollutant in a SIP which would achieve ambient air quality by 1983. Finally, such a source should comply with the "lowest achievable emission rate" (LAER).

3. Summary

Copper smelters are potentially subject to four emissions limitations. These emission limitations differ by stringency, by method of calculation and by applicability, i.e., whether they apply to the smelter as a whole or to individual pieces of equipment. They are the ultimate emissions limit, LAER, BACT and RACT. New Source Performance Standards are usually the same as BACT or a little less stringent because of the time lags in NSPS revisions. NSPS apply only to major pieces of process equipment.

All smelters are required to achieve an ultimate emissions limit sufficient to prevent NAAQS violations at all times and without resorting to dispersion or SCS (production curtailment). This ultimate emission limit is calculated by diffusion modeling and is dependent on the allowable stack height, the weather and topography in the vicinity of the smelter and smelter size. It generally requires over 90 percent capture of SO_2.

The other emissions limits are technology-related and depend on the processing equipment used at a particular smelter. In increasing order of stringency, they are RACT, BACT and LAER. RACT (control of strong SO_2-containing streams) at existing smelters can achieve about 50-70 percent sulfur capture. BACT (for non-reverberatory smelting and dual absorption acid plants) can achieve over 90 percent control. LAER could achieve additional pollution control beyond BACT via the control of fugitive emissions, weak gas scrubbing, etc. Generally, since existing smelters are in non-attainment areas, LAER will apply if these smelters are modified. For the construction of new smelters, LAER, BACT or NSPS may apply depending on whether such a new smelter would be located in a Class II or Class III area, or because it is needed to comply with the ultimate emissions limitation.

If, for technical or economic reasons, an existing smelter is unable to achieve immediately the ultimate emissions limitation, it may continue to operate under a Nonferrous Smelter Order (NSO). As a condition for obtaining an NSO, the smelter must install the most control equipment consistent with its technical and economic circumstances. The NSO would specify a RACT emissions limitation predicated on capacity production and full, effective utilization of the existing pollution control system (if any). The RACT emissions limitation establishes a ceiling on emissions; it is not a license to emit at the specified rate. Put differently, the smelter is still required to employ dispersion and production curtailment techniques to prevent ambient violations during the life of the NSO. Upon termination of the NSO, the smelter would have to comply with the ultimate emissions limitation or close.

C. WATER POLLUTION

1. Background

a. Water Pollution Control Prior to 1972

Until 1972, the Federal approach to water pollution was embodied in two pieces of legislation:

- the Refuse Act of 1899; and
- the 1948 Federal Water Pollution Control Act (including Amendments passed in 1956, 1965, 1966, and 1970).

The Federal Water Pollution Control Act (FWPCA) was essentially the Federal Government's first venture into what was previously almost exclusively a state and local matter. It asserted that the primary responsibility for pollution control remained with the states and gave the Federal Government authority principally for investigations, research, and surveys.

Amendments to the Act in 1956 and thereafter increased the scope of Federal activity in two key ways: first, authorization was made for Federal financial support of municipal water treatment plants; second, a complex procedure was established for Federal regulation of waste discharge through enforcement actions against individual polluters. Interstate polluters were the initial targets of these actions, but eventually authorization was broadened to include both inter- and intrastate pollution.

The FWPCA originally focused on the maintenance of ambient water quality standards; allowable discharges were related to the estimated assimilative capacity of a receiving stream or lake. Enforcement was slow and cumbersome, involving conferences and long waiting periods. As a result, the Act's provisions were the basis of only three civil court actions brought against polluters before 1972.

The Refuse Act of 1899 was an obscure law passed as part of an appropriation act for construction and repair work on rivers. It forbade discharge of any refuse matter (excluding that from municipal sources) into the nation's navigable waters without a permit issued by the Chief of the United States Army Corps of Engineers. The Act was generally unenforced until 1970; thereafter, as concern with pollution increased, the Government began bringing both criminal and civil lawsuits against individual polluters, basing its authority on a 1960 Supreme Court decision which held that, under the Refuse Act, the United States could sue industries to stop them from discharging pollutants into navigable waters without a discharge permit. The Act became unimportant following passage of the FWPCA Amendments of 1972, which included provisions which required permits for all industrial and municipal dischargers.

b. Federal Water Pollution Control Act Amendments of 1972

The Federal Water Pollution Control Act Amendments of 1972 represented a significant policy departure from prior Federal Government approaches to correction of the national water pollution problem. The amended law embodied several significant alterations in the specific objectives, implementation, and enforcement procedures of the Federal Government's antipollution program for the nation's waterways.

As amended, the law aimed "to restore and maintain the chemical, physical, and biological integrity of the Nation's water". As national goals achieved this objective, it called for eliminating pollutant discharges altogether by 1985, and, whenever attainable in the interim, achieving water quality, providing for protection and propagation of fish, shellfish, and wildlife and for recreation in and on the water by 1983 (Section 101a). The law did not, however, actually mandate attainment of these objectives and goals. The no-discharge goal was mandated by 1983 only for categories and classes of nonmunicipal dischargers for which it was "technologically and economically achievable".

Prior law related pollution requirements to a goal of making individual waters clean enough to support one or more beneficial uses--such as fishing, swimming, boating and water supply for homes, farms, and industries--in each case determined by the states to be desirable and feasible. This approach recognized that different waters would, as a practical matter, support different combinations of uses which in turn would require different ambient water quality conditions.

By contrast, the amended law primarily focused, for the purpose of policy objectives, on reducing pollutants rather than on water quality *per se*.

In several respects (e.g., citizen suits, monitoring, retention of local authority) the provisions of the FWPCA roughly paralleled those of the Clean Air Act. The Water Act's special provisions are discussed below.

(1) Establishment of Water Quality Standards

The 1972 Amendments provided that EPA and the states establish water quality standards for the nation's navigable waters. These, however, are secondary, rather than principal criteria for regulating pollution in the nation's waterways. The amended Act no longer focused principally on ambient quality and assimilative capacity of receiving waters. but instead directed EPA and the states to establish discharge requirements for individual industrial and municipal polluters.

By June 1974, the initial process of reviewing and revising interim standards was completed. In October 1974, EPA proposed water quality criteria defining *maximum* limits of acceptability for chemical and physical constituents in United States waters. These criteria are intended to form the scientific basis for any future revision of water quality standards, and in particular the establishment of the 1983 interim goal of providing for the protection and propagation of fish, shellfish, and wildlife and for recreation in and on the water. EPA emphasized, however, that decisions on standards and control measures must also consider the economic and social impact of controlling water pollutants and the practicality and enforceability of the standards and control measures.

(2) Establishment of Effluent Limitations

As mentioned above, the amended Act directed the EPA and the states to establish discharge requirements for industrial and municipal plants as the principal means for regulating water quality. The predominant influence behind this approach was the universal recognition that basing compliance and enforcement efforts on a case-by-case judgment of a particular facility's impacts on ambient water quality is both scientifically and administratively difficult. To minimize the difficulties in relating discharges to ambient water quality, the law required minimum effluent limitations for each category of discharger, based on technological and economic feasibility, regardless of receiving water requirements.

Three critical provisions of the 1972 Amendments governed the establishment of effluent standards for water quality control.

First, a 1977 deadline was set for achieving "effluent limitations for point sources, other than publicly owned treatment works,...which shall require the application of the best practicable control technology currently available..." (Section 301b). This has been called the best-practicable-technology (BPT) standard.

Second, a 1983 deadline was set for achieving "effluent limitations for categories and classes of point sources, other than publicly owned treatment work, which...shall require application of the best available technology economically achievable for such category or class, which will result in reasonable further progress toward the national goal of eliminating the discharge of all pollutants...such effluent limitations shall require the elimination of discharges of all pollutants if the Administrator finds...that such elimination is technologically and economically achievable for a category or class of point sources..." (Section 301b). This has been called the best-available-technology (BAT) standard.

Third, in establishing guidelines for BPT and BAT, EPA was charged to take into account "the age of equipment and facilities involved, the process employed, the engineering aspects of the application of various types of control techniques, process changes, non-water quality environmental impact (including energy requirements), and such other factors as the Administrator deems appropriate..." (Section 301b). In addition, in determining BPT, but not BAT, the Administrator was to consider "the total cost of application of technology in relation to the effluent reduction benefits..." The use of the term "economically achievable" in the BAT definition, however, does introduce similar economic considerations.

Thus, technology and cost considerations are mandatory in the establishment of BPT and BAT limitations. In addition to these considerations, formal public hearings must, by law, be held in conjunction with the establishment of water-quality-related limitations more restrictive than BAT requirements (i.e., limitations imposed where water quality standards are not satisfied by generally applicable minimum effluent standards). These hearings are to focus upon the "reasonable relationship of the economic and social costs and the benefits to be obtained (by the proposed effluent limitation)" (Section 302b).

The Act does not specify that effluent limitations should consist of single numbers (vs. a range) for each industry category, though in practice state authorities and EPA have generally preferred to use single numbers in establishing effluent guidelines.

(3) Establishment of New Source Performance Standards (NSPS)

In addition to issuing effluent guidelines for existing point sources, under the amended Act, EPA must set special effluent standards for new industrial point sources.

The Act implied that process units, as well as entire plants, were subject to new source effluent standards. Distinctions in the setting of new source standards among classes, types, and sizes of facilities were allowed by the terms of the Act.

Best available technology, along with considerations of cost, non-water-quality environmental impact, and energy requirements formed the basis for the New Source Performance Standards. Permits granted on this basis exempt permittees from compliance with any more stringent standards for up to 10 years.

Whether a facility is deemed an existing source or a new source is important for two reasons. First, New Source Performance Standards are for the most part stricter than 1977 standards for existing sources because it is assumed that the latest technology is more easily built into a new facility. Second, the new source permit is issued for a longer period than other permits, thus reducing the potential for periodic tightening of permitted effluent levels. EPA has to prepare and circulate environmental impact statements on major new source permit actions and in the process should review all aspects of the siting decision for the source.

(4) Establishment of Toxic and Pretreatment Effluent Standards

The EPA Administrator must publish a list of toxic pollutants and effluent limitations or prohibitions for them. Toxic pollutants or priority pollutants are defined as those which, when assimilated either directly from the environment or indirectly by ingestion through food chains, will cause death, disease, behavioral abnormalities, cancer, genetic mutations, physiological malfunctions, or physical deformities in any organism or its offspring. Spills of toxic or other hazardous materials are now subject to the same regulatory framework--for prevention and Federal cleanup costs--that previously existed only for oil spills.

The criteria for these standards are to be developed so as to protect any potentially affected organisms in any receiving waters. Economic considerations are absent from this statutory standard-setting procedure.

In July 1973, EPA designated 12 chemicals used in manufacturing as toxic water pollutants, including the pesticides aldrin, dieldrin, endrin, DDT and its derivatives DDE and DDD; the pesticide compound toxaphene; cadmium, mercury and cyanide; and the industrial chemicals benzidine and PCB (polychlorinated biphenyls). These pollutants are toxic in very low concentration, with the exception of benzidine, which was included because of its ubiquity and known carcinogenic properties. EPA is currently developing effluent standards governing the discharge of these and other toxic pollutants. EPA has been studying additional chemicals such as arsenic, selenium, chromium, lead and asbestos for possible inclusion on the list.

The Administrator must also issue pretreatment standards requiring an industrial facility discharging into a municipal sewage treatment plant to pretreat its effluent so that it does not interfere with the operation of or pass through the plant without adequate treatment. Because roughly one half of all industrial facilities discharge their wastes into municipal systems, pretreatment standards are considered essential to achieving control over industrial effluents.

2. Specific Federal Provisions Affecting Copper Mining, Smelting and Refining

a. Best Practicable Technology Currently Available (BPT)

These effluent limitation guidelines have to be met by 1977 by industrial dischargers of wastewater pollutants. Only point sources and identifiable outfalls such as pipes and sewers are affected by these guidelines.

The copper mining and milling sector was divided into three categories for the purpose of BPT Guidelines.

- Copper mines require "lime and settle" treatment of all wastewater discharges.
- Copper mines that include leaching have to meet a zero discharge requirement.
- Copper mines that include froth flotation facilities require lime and settle treatment of all wastewater discharges.

The copper smelting and refining sector was divided into three categories for the purpose of BPT guidelines.

- Primary smelters and adjoining refineries have to meet a zero discharge requirement. Excess rainwater can be discharged after lime and settle treatment.
- Primary refineries in net evaporation areas have to meet a zero discharge requirement.

- Primary refineries in net rainfall areas can discharge wastewater after a lime and settle treatment.
- In addition, the secondary copper industry has to meet a zero discharge requirement.

b. Best Available Technology Economically Achievable (BAT)

These effluent limitation guidelines have to be met by 1983 by industrial dischargers of wastewater pollutants.

The copper mining and milling sector was divided into two categories.

- Copper mines will require lime and settle treatment of all wastewater discharges.
- Copper mines with flotation or leaching facilities have to meet zero discharge.

In the copper smelting and refining sector, the BAT requirements are the same as the BPT requirements discussed above.

c. New Source Performance Standards (NSPS)

These effluent limitations guidelines have to be met by new sources constructed after the guidelines were in effect. In all cases, NSPS are the same as the BAT guidelines discussed above.

D. OTHER REGULATIONS NOT CONSIDERED IN THE STUDY

The copper industry is affected by governmental regulations of various types on the Federal and State level. Some of these regulations have been in existence for a long time and therefore their effect remains embedded in both the historical data and in the future projections as estimated by the econometric model. An example would be the regulations of the Internal Revenue Service. There also exist more recent regulations many of which have been proposed and others that are anticipated over the impact analysis period of 1974-1987. While these regulations fall into a broad "environmental" category, many of them will not be administered by the EPA. These regulations are expected to impact the copper industry in some fashion over the analysis period. Other regulations, which could affect the copper industry, are either being developed or are too new to allow detailed analysis of their economic impacts.

The following Acts and Regulations have not been considered in the analysis.

1. New Ambient or Emission Standards for Elements Such as Lead and Arsenic

Depending on the nature of these standards, the compliance cost would vary widely. A differential impact within the industry is expected since

Tacoma, Anaconda and El Paso handle a feed material containing significant amounts of arsenic compared to the remaining smelters and Asarco-El Paso combines copper smelting and lead smelting at the same location.

2. Revised Effluent Limitation Guidelines for Toxic or Priority Pollutants

3. Limitations on Non-Point Sources of Aqueous Effluents Such as Seepage from Tailings, Ponds, Etc., Which Might be Required for Several Reasons Including the Safe Drinking Water Act

4. The Solid Waste Disposal Act

5. Auxiliary Regulations or Administrative Interpretations

Those which can have a significant impact are those governing plant upsets or the ability to maintain production when the pollution control equipment is being repaired; regulations covering the methods sampling and for data analysis (e.g., six-hour running averages versus fixed time averages), sampling techniques (e.g., opacity caused by acid mist is measured as a particulate) and so on.

6. Regulations Under the Occupational Health and Safety Act on In-Plant Emissions of Inorganic Arsenic, Sulfur Dioxide, Lead, Etc.

7. Federal and State Land Management and Withdrawal Regulations

8. MESA Health and Safety Standards

CHAPTER IX

NOTES

1. Based on Journal of Air Pollution Control Association, 27-10, October, 1977, pp. 943-7.

2. The primary ambient air quality standards for sulfur dioxide are 80 micrograms per cubic meter-annual arithmetic mean - and 365 micrograms per cubic meter-maximum 24-hour concentration not to be exceeded more than once per year. The secondary standard is 1,300 micrograms per meter maximum 3-hour concentration not to be exceeded more than once per year.

3. The primary ambient air quality standards for particulate matter are 75 micrograms per cubic meter-annual geometric mean - and 260 micrograms per cubic meter-maximum 24-hour concentration not to be exceeded more than once per year. The corresponding secondary standards are 60 and 150 micrograms per cubic meter.

4. If an existing smelter were using Best Available Control Technology or BACT (defined to be the same as NSPS in the Tall Stacks Policy) such a smelter could use unlimited stack height, but no allowance for SCS in calculating the ultimate emission limit for that plant. Since unlimited stack height was also permitted for dispersing RACT emissions, this meant that the maximum permissible emission for a BACT smelter would be less than the RACT emissions limit.

5. Code of Federal Regulations, Vol. 40, 60.160 - 60.166, inclusive, subpart P. The 1977 Amendments do explicitly require periodic review of the NSPS.

6. The Clean Air Act Amendments of 1977 amended the New Source Performance Standard provision (Section 111) to require EPA to upgrade each standard to reflect the best system of continuous emission reduction that is economically achievable. Best Available Control Technology may be even more stringent than NSPS.

   New and modified major sources require permits before they can be constructed.

X. PRODUCTION COST AND CAPACITY IMPLICATIONS OF ENVIRONMENTAL REGULATIONS

A. INTRODUCTION

The purpose of this chapter is to describe the implications of environmental regulation for production costs and for the maintenance and growth of industry capacity over the period 1974-1987.

Section B presents our estimates of the costs borne by industry as a consequence of Federal environmental regulation. As noted in Chapter IX, the scope of the analysis does not include all Federal environmental regulation, but rather concentrates on those associated with the Clean Air Act Amendments of 1970 and 1977 and the Federal Water Pollution Control Act. These Acts and their implementing regulations currently account for the preponderance of environmental costs faced by the copper industry.

The costs of meeting these regulations as estimated in this report include the capital, operating and maintenance costs that would be incurred by the industry over the period 1974-1987 for pollution control. These estimates exclude other costs that result from regulations such as an increase in business risk, disruption of the normal capital budgeting and investment planning process, changes in the legal and administrative costs of doing business, etc. While the estimation of costs through 1977 is a fairly straightforward procedure in the sense that published data and engineering cost analysis provide good estimates, the projection of incurred costs requires information on the extent and rate of compliance, the cost and availability of production and pollution control technology, and industry growth (contraction). The fundamental compliance assumption underlying the cost estimates is that all smelters will continue to rely on acid plants, tall stacks, and SCS to meet National Ambient Air Quality Standards during the considered period. The corresponding technological assumption is that there will be no fundamental change in the relative cost and nature of pollution control technology, and, therefore, the industry will continue to use acid plants for control of strong gas streams and improved collection and tall stacks for the dispersal of weak gas streams.

Various capacity growth scenarios were examined. The cumulative capital investment is estimated to range (depending on the particular growth scenario) between $1.7 billion and $1.9 billion in 1974 dollars over the period 1974-1987. Cumulative operating cost is estimated to range between $1.0 billion and $1.1 billion in 1974 dollars over the same period. It is important to note that 30-40 percent of the estimated capital costs have already been incurred. The conversion of reverb smelters to alternative smelting technology (mandated by the Clean Air Act Amendments of 1977) represent a major portion of the future cost. By comparison, operating and maintenance costs are estimated to steadily increase from about $42 million a year in 1977 to $90 million a year in 1987. It is important to note that these expenditures will not be sufficient for the smelters to meet the ultimate emissions limit in all cases. In other words, while this expenditure will enable the smelters to switch to non-reverberatory smelting techniques and achieve a higher level of emissions control, the smelters will not always achieve ambient air quality through the use of permanent emission controls alone plus the use of new stacks that are no taller than two-and-one-half times building height.

In a capital-intensive, mature industry like copper, decisions on capacity change are motivated by a set of complex considerations. This complexity has increased substantially as a result of recent requirements for case-by-case review, analysis of alternate sites, etc. Section C examines how environmental regulations affect the maintenance and expansion of copper smelting capacity. We conclude that existing smelters are faced with a variety of economic, environmental and technical constraints which, taken together, essentially preclude growth at existing reverberatory smelters before 1985 and allow for only limited growth, if any, at non-reverberatory smelters. Because of the long lead times required to completely rebuild existing facilities around a non-reverberatory smelting process or to construct entirely new smelters, major increments of capacity will be available only after 1985.

These conclusions result from a detailed examination of the technical, economic, and legal environment facing new and existing smelters. They do not flow from the investment sector of the econometric model described in Chapter XI. The investment model seems to provide a reasonable explanation of capacity formation in a world where incremental expansion of existing production facilities is both economic and legal. In particular, it provides a good explanation of growth prior to active Federal involvement in limiting environmental pollution. However, the investment model does not capture the technology forcing nature of Federal pollution control efforts and the differential situation of individual smelters, which is crucial to the legality and profitability of investment in the context of Federal environmental regulation.

In view of these complexities, we cannot postulate a unique growth scenario for the industry up to 1987. We have, therefore, analyzed several combinations of capacity expansion paths, recognizing that not every path is equally plausible but that each path is a reasonably plausible response to the external market and regulatory constraints. The components of these paths are the following: 1) all existing smelters will be in compliance with the requirements of the 1977 Amendments by January 1, 1988; 2) some smelters will choose to shut down instead of complying with the ultimate emission requirements; 3) one or more grass-roots smelters will come onstream during the period 1985-1987; 4) additional leach-electrowinning capacity will be brought onstream during 1978-1987; and 5) four non-reverberatory smelters that are at or close to complying with the New Source Performance Standards (Inspiration, Hidalgo, Anaconda, and Kennecott) will be allowed to increase capacity without installing incremental pollution control beyond NSPS.

B. AIR AND WATER POLLUTION CONTROL COST ESTIMATES

This part describes the procedure used to estimate air and water pollution control costs over the period 1974-1987.

The costs of meeting pollution control regulations, as estimated in this report, include the capital, operating and maintenance costs associated with pollution control equipment that would be incurred by the industry. These estimates exclude other costs that result from regulation such as an increase in business risk, disruption of the normal capital budgeting and investment planning process, changes in the administrative and legal cost of doing business, etc. Any production losses associated with the operation of pollution control systems are, under the approach adopted here, treated as reductions in productive capacity. In particular, the value of production losses is not added to pollution control equipment costs to yield a "total cost" of pollution control. Instead, the economic effect of any such production losses is reflected by changes in the price and quantity of copper production.

The value of by-product recoveries associated exclusively with pollution control (sulfuric acid is the leading example) is treated as a credit against the operating cost of pollution control equipment. This convention reflects the judgment that pollution control equipment would not be installed as an incidental part of a profitable by-product recovery venture. By contrast, European and Japanese smelters have traditionally found pollution control via the manufacture of sulfuric acid to be profitable because of credits from by-product sales. United States smelters are isolated and transportation costs to distant markets have limited the potential for profitable recovery of sulfuric acid. Thus, prior to 1970, the Japanese and European smelters manufactured sulfuric acid from smelter gas in almost all cases, whereas United States smelters did so only if nearby acid markets were available. It should be noted that the total cost of complying with regulations, while indicative of the industry's obligation, is not sufficient as an input into an economic impact analysis. These costs affect production costs only when they are incurred and the timing of these costs affects the nature and magnitude of the economic impact results.

1. Historical Costs (1970 to 1977)

Historical costs were derived after a procedure involving: 1) an industry survey; 2) compilation of pollution control equipment inventories; 3) review of engineering, trade journal, and government literature regarding pollution control equipment costs (capital, operating and installation); and 4) validation (and adjustment) of the estimates generated in the first three steps after industry review or engineering cost analysis when data sources conflicted.

Despite precautions, we do not believe these or any other estimates are exact. The scope for differing judgments regarding partitioning between the pollution control and production costs are large; complete coverage of all costs is probably impossible; and company data, when accessible, are not designed to unambiguously identify pollution control expenditures. Nevertheless, we believe that researchers who follow our procedures and adopt our cost conventions would arrive at similar conclusions.

Originally, we conducted an industry survey which sought data on actual, planned, and anticipated pollution control expenditures. Companies were asked to provide sufficient information regarding pollution control costs to allow independent evaluation and to distinguish between Federally and locally mandated costs. All the major firms were contacted. The survey results were disappointing. The responses received covered only about half the industry and the data that was provided was highly aggregated in most cases. However, the survey provided some useful information. It established that almost all mandated pollution control costs were related to Federal programs; state and local regulations seemed to require minimal additional expenditures. Unfortunately, the data lacked sufficient coverage and detail to permit generalization to the industry as a whole.

An alternative approach proved more successful. The first step was to identify the installation of pollution control equipment after 1970[1]. This inventory was constructed after a careful review of Annual Reports, 10-K financial reports (annually filed by Corporations with the Securities and Exchange Commission), trade journals, and government reports. In addition, we directly contacted corporate officers to confirm published information or for supplemental information. Having identified the stock of pollution control equipment and changes in the stock, we employed the above sources, engineering cost estimating formulas, and the survey results to derive industry-wide capital and operating costs. The final cost estimates were reviewed by government and industry. Table X-1 shows these estimates.

2. Projected Costs (1978-1987)

In order to project incurred pollution control costs, it is necessary to know the size of the industry and the nature and extent of compliance with air and water pollution control costs. Various growth scenarios were considered. The basis for these growth scenarios is discussed in Part C, below.

The following compliance assumptions are made in all cases:

- Smelters will not embark on expansions permissible under NSO's if these expansion routes are inconsistent with the achievement of ambient air quality via permanent controls in 1988.

- No reverberatory furnace smelter will convert to an alternative smelting technology before 1985.

- Neither Kennecott at Ely nor Phelps Dodge at Douglas will control sulfur dioxide emissions; they will either remain open until 1988 or shutdown in 1983.

TABLE X-1

ESTIMATED HISTORICAL POLLUTION CONTROL COSTS

(Millions of 1974 dollars)

Year	Capital Expenditures	Operating and Maintenance Costs[a]
1970	20.9	17.7
1971	30.0	15.9
1972	146.4	37.5
1973	204.6	37.4
1974	226.0	59.6
1975	240.8	52.0
1976	156.0	55.3
1977	90.0	70.1

NOTES: [a] Increases in total annual variable costs due to pollution abatement and control, estimated at 0.5¢/lb. in 1970 and 1971, 1.0¢/lb. in 1972 and 1973 and 1.8¢/lb. in years 1974-1977. The estimates given here are obtained by multiplying production levels in these years (domestic refined copper production from domestic and foreign ores, as reported by the U.S. Bureau of Mines, adjusted for electrowinning capacity) by the per unit (¢/lb.) cost estimates.

SOURCE: Arthur D. Little, Inc. estimates.

- All operating smelters will install technology for collection of fugitive emissions.

- No reverberatory furnace smelter will either upgrade its acid plants or add acid plant capacity.

- Four non-reverberatory smelters (Inspiration, Hidalgo, Kennecott-Garfield, and Anaconda) will either expand capacity by 1981 or maintain current capacity; Garfield and Anaconda would have to upgrade their acid plants to NSPS caliber before an expansion is permitted.

- Applicable BPT and BAT effluent guidelines will be met at all mines, mills, smelters and refineries, as required.

In view of the Clean Air Act Amendment's requirement for meeting ambient standards by 1988 and the continuing litigation and rulemaking involving individual smelters, the assumptions require further explanation.

In the context of present technology, the 1977 Clean Air Act Amendments require almost all smelters to employ non-reverberatory furnaces and/or weak gas scrubbing to meet ambient standards. (An exception is the White Pine smelter, a small smelter which employs concentrates of low sulfur content. This smelter can meet ambient air quality standards without employing any emission control technology). If a smelter did not satisfy this requirement by 1988, it presumably would have to close. We consider weak gas scrubbing to be prohibitively expensive. For example, the cost of SO_2 control using acid plants is about 1 to 2 ¢/lb. of SO_2 removed. The corresponding cost for weak gas scrubbing is 5 to 7 ¢/lb. of SO_2 removed[2]. We believe that weak gas scrubbing costs could be even higher. It appears to us that the industry would prefer a process change to non-reverb technology over end-of-pipe treatment such as weak gas scrubbing.

The first assumption (that smelters will not embark on expansion routes permissible under NSO's if these routes are inconsistent with 1988 goals), reflects the capital intensity of smelting process changes and the long time horizon over which such changes are utilized. This implies that any changes which will continue the reliance on reverb smelting will not be undertaken.

The assumption that no reverberatory smelters convert to alternate technology before 1985 does not necessarily imply that these smelters would not comply with the Act. Smelters could still meet the 1988 date (when the second and final NSO would expire) by completing all requisite engineering and design work by 1984 and commencing conversion in 1985. These would be about the latest possible dates consistent with meeting the Act's requirement. Because of the decidedly unfavorable economics of conversion (see Part C, below), we do not anticipate large expenditures for conversion before 1985.

Without passing judgment on their economic condition, we do not expect that Kennecott at Ely or Phelps Dodge at Douglas will invest in sulfur dioxide control. Both companies have repeatedly claimed that sulfur dioxide control was uneconomic at these smelters and that they would close the smelters rather than invest in sulfur dioxide control. Lacking evidence to the contrary, we believe it prudent to assume these smelters will continue to operate without sulfur dioxide control as long as possible. For a sensitivity analysis, we have considered a case where these smelters close in 1983 at the end of the first NSO on the basis that their application for the second NSO would not contain any plans for complying with the requirements of the Act by 1988 and would be denied for that reason.

We do expect that all operating smelters will invest in fugitive emission control systems. Some smelters (for example, Garfield and Asarco at El Paso) have already installed such systems to avoid sulfur dioxide and particulate violations that are traceable to fugitives. In addition, effective fugitive control appears to be essential to limiting ambient concentrations of lead and arsenic. Both lead and arsenic will be regulated. Of course, there is no way of knowing if the fugitive emissions system described below would meet currently undefined standards for these substances.

At the present time, there are four non-reverberatory smelters in the United States. They are: Inspiration, Phelps Dodge-Hidalgo, Kennecott-Garfield, and Anaconda. The first two are in compliance with NSPS and the latter two could meet NSPS by upgrading their acid plants from single absorption to double absorption. If these four plants at NSPS were meeting their ultimate emission standard, they might be allowed to expand without incremental pollution control as long as the emissions increase did not exceed that allowed under PSD regulations. If these smelters at NSPS were not achieving their ultimate emissions standard, they would be in a non-attainment area. They could expand only by emissions tradeoffs against other sources or by demonstrating that they are at the lowest achievable emissions rate (LAER). For a sensitivity analysis, we have considered a case where these smelters are allowed to expand by 1981 without having to install emission reduction equipment beyond NSPS.

The assumption that no reverberatory furnace smelter will upgrade its acid plant per se is somewhat arbitrary but reflects our view that in comparison with the uncontrolled reverb emissions, the improvement to be achieved via acid plant upgrading is marginal. The alternative is to attempt to predict the outcome of the untried NSO process where such an upgrading could be mandated.

Taken together, these assumptions imply that there will be little additional permanent control of smelter emissions beyond that currently employed, excepting improved collection of fugitive emissions and perhaps improved pollution control at Anaconda and Garfield.

With this background, the estimation of operation and maintenance (O&M) costs for air pollution is straightforward. We assume that fugitive control systems will rely on building enclosure, especially of the converter aisle, and secondary hooding of process equipment. The collected gases would be filtered in a baghouse and exhausted via the main stack. This system roughly corresponds to the type of fugitive control system used in some foreign smelters. Definitive estimates for the control of converter aisle emissions are not available. Our order-of-magnitude estimates for a secondary and tertiary gas collection system and treatment by a baghouse suggest a range from $10 and $20 million per 100,000 tons/year of capacity or about $300 million for the entire industry. This investment was spread uniformly over the eight-year period (1979-1986). The direct O&M costs for fugitives control are shown in Table X-2. The fugitive gas stream is essentially at ambient temperatures and is much larger than the other streams from the process units which will also be exhausted via the main smelter stack. As a consequence, the stack gas will require reheating to increase buoyancy and achieve the proper degree of dispersion necessary to meet NAAQS. Table X-2 shows two estimates for the O&M costs of fugitives control; the first assumes that this reheating will be achieved with waste heat and the second assumes that the reheating is achieved with clean fossil fuels.

O&M costs associated with a double absorption acid plant are shown in Table X-3. These costs are about 1.95¢/lb. of copper. As shown in Table X-2, the O&M costs for fugitive control range between .65¢ and 2.3¢/lb. of copper depending upon the reheating technique used. The sum of these operating costs is 2.7 to 4.3¢/lb. We have used the significantly lower cost associated with the first approach in the impact analysis and used the latter value in the sensitivity analysis, because it is not certain that reheating is required in all cases and because waste heat could be used. The 2.7¢ was normalized and rounded off to 2.5¢/lb. to account for our assumption that neither Douglas nor McGill will install acid plants.

These unit costs are multiplied by production estimated in the model to yield total O&M costs in a given year.

Water pollution costs beyond 1975 were estimated for meeting effluent limitations guidelines (BPT and BAT levels) for point-source discharges.

There are two basic sources of cost data: the Guidelines Documents[3] for the copper mining, milling, smelting and refining sectors; and a study by the American Mining Congress, "Study of the Cost of Compliance with Federal Water Pollution Control Act" (1976).

The costs for meeting BPT and BAT requirements are given as:

TABLE X-2

OPERATING AND MAINTENANCE (O&M) COSTS FOR FUGITIVES CONTROL

(at a 100,000 ton/year smelter)

A. Capital Investment $≈15 Million

	$/Year	
B. O&M Costs	Without Reheating	With Reheating
Electricity--34 Million kWh @ 1.5¢/kWh	$ 510,000	$ 510,000
Labor--1 man/shift @ $10/hour	79,000	79,000
Supervision--@ 15% Labor	12,000	12,000
Maintenance supplies--@ 4% Capital Investment	600,000	600,000
Plant overhead--100% Labor and Supervision	91,000	91,000
Reheating--2.2x10^6 Million Btu/year @ $1.50/Million Btu	-	3,300,000
	1,292,000	4,592,000
C. Unit Costs		
$/ton of copper	12.92	45.92
¢/lb. of copper	0.65	2.30

SOURCE: Arthur D. Little, Inc. estimates.

TABLE X-3

OPERATING AND MAINTENANCE (O&M) COSTS FOR A DA ACID PLANT ON CONVERTER GAS

A. Capital Investment $≈30 Million

B. O&M Costs

	$/Ton Acid
Power[a]--250 kWh x 1.5¢/kWh	$ 3.75
Fossil fuel[a] for reheating--1 Million Btu x $1.50	1.50
Labor--6 me [illegible] ift @ $10/hour	2.50
Supervision- [illegible] 15% labor	0.38
Maintenance supplies--@ 4% Capital Investment	6.44
Plant overhead--100% Labor and Supervision	2.88
Total	$17.45 $17.50 (rounded)

C. Unit Costs

$$\frac{\$17.50}{\text{Ton Acid}} \times \frac{\text{3 Tons Acid}}{\text{Ton Sulfur}} \times \frac{\text{31 S}}{\text{25 Cu}} \times \text{0.60 S Recovery}$$

= $39.02/ton Copper

or 1.95¢/lb. Copper

NOTES: [a] Some data in the published literature, "Energy Use Patterns in Metallurgical and Nonmetallic Minerals Process--Phase 4", PB 245 759, is over twice the numbers used here.

SOURCE: Arthur D. Little, Inc., estimates.

	(Millions of 1974 Dollars)	
	Capital Investment	Annualized Costs
Guidelines Documents	6.6	1.47
American Mining Congress	267.0	158.70

We found several errors in the Guidelines Document which indicate that those costs could be low. On the other hand, we have not been able to independently derive the American Mining Congress numbers. It is possible that they contain costs for the control of non-point source discharges, which were not considered in the Guidelines Document.

We have used the following cost figures for control of point-source discharges:

Capital Investment (1979-1985) = $20 Million
O&M Cost = 0.1¢/lb. Copper

The total cost estimates over the period 1974-1985 are shown in Table X-4.

C. MAINTENANCE AND EXPANSION OF CAPACITY

The objective of this section is to explain the plausible range of growth scenarios considered for impact analysis. Part 1 examines whether existing capacity can be maintained in view of environmental regulations and the financial state of some smelters. This discussion leads to a quantification of existing capacity which would likely be maintained through 1987. Part 2 examines potential growth through 1987, which could be achieved by modification and reconstruction of existing smelters or by the construction of new smelters. The total potential capacity is the sum of baseline capacity and the capacity increments available from new and altered facilities. Part 3 aggregates the results of the previous parts to define the capacity scenarios.

All four stages of primary copper production (mining, milling, smelting and refining) are affected by Federal environmental regulations. Mining and milling are affected most by water and solid waste regulations; smelting by air regulations; and refining by water regulations. The discussion of capacity focuses exclusively on the smelting stage of production because, although environmental regulations increase the cost of production in mining, milling and refining (which would tend to reduce capacity formation), the cost increases are not large and the currently applicable Acts and regulations do not require fundamental changes in production technology.

Our review of the applicable regulations and associated compliance costs indicates that Federal pollution regulations are unlikely to change directly and significantly the economics of expansion for these stages of production. This is not to say that the prospects for investment in mining and refining are independent of the growth or contraction of smelting capacity.

TABLE X-4

ESTIMATES OF POLLUTION ABATEMENT AND CONTROL EXPENDITURES BY THE UNITED STATES COPPER INDUSTRY[a], 1974-1987

(In millions of 1974 dollars)

Year	CONSTRAINED CAPACITY					REDUCED CAPACITY				
	Capital Expenditures[b]			Operating and Maintenance Costs[e]	TOTAL	Capital Expenditures[b]			Operating and Maintenance Costs	TOTAL
	Non-reverberatory Related Capital Expenditures	Reverberatory Conversion Investment[c]	Total			Non-reverberatory Related Capital Expenditures	Reverberatory Conversion Investment[d]	Total		
1974	226.0	-	226.0	57.4	283.4	226.0	-	226.0	57.4	283.4
1975	240.8	-	240.8	49.3	290.1	240.8	-	240.8	49.3	290.1
1976	156.0	-	156.0	48.8	204.8	156.0	-	156.0	48.8	204.8
1977	90.0	-	90.0	42.3	132.3	90.0	-	90.0	42.3	132.3
1978	60.0	-	60.0	98.0	158.0	60.0	-	60.0	98.0	158.0
1979	40.0	-	40.0	88.2	128.2	40.0	-	40.0	88.2	128.2
1980	40.0	-	40.0	89.5	129.5	40.0	-	40.0	89.5	129.5
1981	40.0	-	40.0	89.8	129.8	40.0	-	40.0	89.8	129.8
1982	40.0	-	40.0	89.6	129.6	40.0	-	40.0	89.9	129.9
1983	40.0	156.5	196.5	90.0	286.5	40.0	126.7	166.7	78.6	245.3
1984	40.0	156.5	196.5	89.8	286.3	40.0	126.7	166.7	78.4	245.1
1985	40.0	156.5	196.6	90.1	286.6	40.0	126.7	166.7	78.5	245.2
1986	40.0	156.5	196.5	90.2	286.7	40.0	126.7	166.7	78.5	245.2
1987	-	156.5	196.5	90.0	246.5	-	126.7	126.7	78.4	205.1
1974-1987	1,092.8	782.5	1,875.3	1,103.0	2,978.3	1,092.8	633.5	1,726.3	1,045.6	2,771.9
1978-1987	380.0	782.5	1,162.5	905.2	2,067.7	380.0	633.5	1,013.5	847.8	1,861.3

NOTES: See Table XII-2, page XII-11.

In fact, the cost methodology partially recognizes their interdependence by assuming that relative capacity ratios are maintained across the stages of production. Smelting is singled out for special examination because the nature and costs of compliance are such that capacity maintenance and expansion at this crucial stage of production could be significantly affected. Put another way, if the supply of refined copper over time is directly affected by environmental regulation, it will be manifest by bottlenecks in smelting.

1. Capacity Maintenance

Existing smelter capacity can decrease over time because of:

- smelter closure;
- declining productivity of production inputs, especially deterioration of capital equipment; and
- inability to produce at nameplate capacity because of changes in operating practice, e.g., breakdown of permanent emission control equipment or production curtailment to meet ambient air quality standards.

Two old smelters (Phelps Dodge at Douglas, Arizona, and Kennecott at Ely, Nevada), representing 9 percent of domestic capacity, appear to be in danger of closing. Prior to the passage of the Clean Air Act Amendments of 1977 their operators claimed that these smelters would close rather than install sulfuric acid plants to control sulfur dioxide emissions. Kennecott did close its Ely smelter for several months, allegedly in response to impending pollution control requirements. The smelter was reopened following a District Court ruling in favor of Kennecott.

The Clean Air Act Amendments of 1977 would allow both smelters to continue operating without sulfur dioxide control systems if the alternative were closure. This exemption does not apply to other air pollutants. However, even assuming that neither must now install sulfur dioxide control equipment, continued operation of these facilities is debatable. Consequently, in order to bound the range of probable growth estimates, we alternatively assume both smelters close, in one case, and both remain open, in another. We assume in the first case that these smelters would close in 1983, at the expiration of their first NSO. This assumes that their application for a second NSO would not contain any plans for complying with the 1988 requirements via permanent emission control and would be denied for that reason.

There is a finite probability that other smelters will close permanently under present air pollution and health-and-safety regulations. Forthcoming OSHA in-plant arsenic regulations would appear to affect the Tacoma, Anaconda, and El Paso smelters more severely than the other smelters. Likewise, EPA's forthcoming ambient lead standard could affect most smelters to varying degrees. Because these regulations have not yet been published it is premature to speculate on their closure implications, if any. For analyzing the effect of capacity reduction, we assume a case where one other smelter, in addition to Douglas and Ely, will close in 1983.

Existing capacity could be affected by falling productivity of labor and capital. Although labor productivity has failed to increase over the last few years, there is little evidence to suggest a permanent decline in labor productivity. Furthermore, one would expect changes in labor productivity per se to affect production or output but not capacity. New Source Performance Standards are relevant to the replacement and overhaul of deteriorating process equipment. Under certain conditions, process equipment cannot be overhauled unless additional pollution control equipment is also installed. Because of NSPS, firms, in principle, could decide to forego the cost of overhaul and replacement so as to avoid additional pollution control expenditures. Through this mechanism the effective capacity might decrease through time. However, we believe that NSPS will have no measurable impact on the preservation of existing capacity. Most process units subject to NSPS (multi-hearth roasters, reverberatory furnaces and converters) are relatively simple pieces of process equipment. Excepting serious accidents, all can be, and are, maintained indefinitely at design specifications through normal repair and maintenance. Consequently, the preservation of existing capacity would rarely, if ever, invoke the reconstruction or new equipment provisions of the NSPS. It is, therefore, assumed that New Source Performance Standards will not affect the rated capacity of any existing domestic smelter.

The utilization of existing capacity can be seriously affected by the need to meet ambient air quality standards. It is quite common for some smelters to reduce operations during periods of adverse meteorological conditions (for example, inversions)[4]. There is no definitive data to allow precise estimates of the capacity impact of employing production curtailments to achieve sulfur dioxide standards. Our discussions with industry representatives suggest that at smelters employing the control of strong streams, the use of SCS results in an effective decrease in capacity of about 10 percent. For the purposes of a sensitivity analysis, we have assumed a 10 percent reduction in capacity.

It should be noted that the effect of ambient standards on effective (usable) capacity depends on the monitoring strategy adopted by pollution control agencies. Because fugitive emissions follow paths different from stack emissions, monitors sited to measure stack emissions do not necessarily record the ambient impact of fugitive emissions. To date the practice has been to monitor primarily for stack rather than fugitive emissions, because these emissions account for over 90 percent of total emissions. There is some scattered evidence, from diffusion modeling by EPA and industry, suggesting that fugitives may be leading to frequent ambient violations. This evidence has not been sufficient to lead to major changes in the monitoring strategy. If additional data indicate that fugitives are a serious problem, the implications for existing effective capacity are unclear. Depending on the frequency of the ambient violations, and the techniques to alleviate these violations, the capacity impact could vary over a wide range.

In summary, we expect that existing industry capacity will be maintained through the period of this analysis. The major uncertainties are:

- whether three smelters will close;
- the precise effect on effective capacity of employing production curtailments to meet ambient standards;
- the effect of fugitive emissions on ambient air quality (and therefor on capacity); and
- the development of new EPA and OSHA standards.

In all but the latter two cases, sensitivity analysis is used to assess the quantitative effect of alternative assumptions.

2. Capacity Expansion

An increase in primary copper capacity downstream of mining and milling can be achieved in four ways:

- Construction of new greenfield smelters (i.e., smelters in new locations which were previously undeveloped);
- Alteration of existing smelters to achieve expanded throughput (this can be coupled with the replacement of obsolete capacity, in some instances);
- Hydrometallurgical processing; and
- Increasing the copper content of the smelter feed material.

This section examines potential capacity expansion from new and modified smelters. Other means of increasing refined copper production, for example, through hydrometallurgical processing of oxide or sulfide ores or through increased reclamation of scrap, offer limited opportunities for increased production above current levels. In addition, there is little possibility of significantly increasing the copper content of the smelter feed material since current beneficiation techniques routinely produce copper concentrates that approach the theoretical compositions of the copper sulfide minerals.

a. New Smelters

The copper industry has traditionally preferred to rely on incremental expansion at existing sites rather than to construct new smelters. In the last 20 years, only one new smelter, Phelps Dodge's Hidalgo, New Mexico smelter, has been built in the United States. Nevertheless, new smelters can provide major capacity increments and cannot be ignored as a potential source of growth.

As discussed in Chapter IX, new smelters must meet New Source Performance Standards, and be able to meet Ambient Air Quality Standards solely through the use of constant emission control equipment with no allowance for tall stacks. Emissions cannot exceed the allowable PSD increment for the area in which such a smelter would be located. These requirements would certainly make it impossible to build a new reverberatory smelter (something nominally permitted under NSPS for smelting of impure concentrates) unless cost-effective weak gas scrubbing systems were available.

Non-reverberatory furnace smelters achieve a much higher level of emissions control and consequently, much lower stack emissions. Assuming that all emissions are treated in NSPS calibre equipment, the stack emissions could still violate ambient standards under certain meteorological conditions; for example, conditions that cause fumigation. Assuming that such meteorological conditions need not be used in the calculation of the ultimate emissions limit, the stack emissions would not violate ambient standards and such smelters would neither exceed the Class II significant deterioration increments nor, with careful siting, would they impinge on Class I areas.

A potential problem is that it is extremely difficult to capture all emissions. A new smelter employing NSPS calibre control technology, secondary hooding, and building enclosure could still emit about 3 percent to 4 percent of the sulfur dioxide in the form of low-level fugitives. For a standard sized smelter, preliminary diffusion modeling[5] indicates this emissions rate would violate the ambient sulfur dioxide standard for several kilometers around the smelter. If further research were to validate the preliminary analysis, and if fugitives could not be economically controlled, new smelters could not be built.

There exist newer continuous processes that eliminate the conventional converter aisle which is the major source of fugitive emissions. However, these processes cannot be used in this mode for the bulk of the concentrates produced in the United States[6]. Some processes (e.g., Mitsubishi) are more flexible in this regard than others. Based on this and the fact that monitoring data on fugitives is unavailable, we assume that environmental regulations will permit new smelter construction.

Assuming that new smelters can be constructed, the effect of environmental regulation on new construction is limited to increasing the timing, the capital, operating, and locational cost of new smelters. A major smelter construction project requires the following steps:

- decision that extra capacity is needed;
- prefeasibility studies--preliminary evaluations of several alternatives;
- process design and detailed engineering of the selected approach;
- construction;
- startup and shakedown; and
- bringing the plant to full capacity.

Construction alone typically takes three years and startup and shakedown generally takes a year. The Inspiration and Anaconda smelters, which converted to electric furnaces, have experienced major delays in achieving reliable production. Given the present depressed state of the copper industry and the fact that there are no firm plans for any new smelter construction in the United States, we do not expect new smelters to come on-stream and reach rated capacity until 1985.

In order to bound the range of likely possibilities, it is first assumed that no smelters are constructed until 1987. As an alternative, it is assumed that one large (200,000 short tons/year) smelter comes on-line and achieves full capacity in 1985 and another smelter of the same size begins operations in 1987.

b. Expansion of Existing Capacity

EPA policy makes a sharp distinction between smelters using dispersion techniques and smelters using emission controls alone for meeting ambient standards. A reverberatory furnace smelter (which relies on SCS and dispersion) cannot increase emissions beyond the RACT limitation contained in its Nonferrous Smelter Order. A non-reverberatory furnace smelter using NSPS caliber technology could or could not increase its level of emissions depending on the ultimate emissions limit and its location in an attainment or nonattainment area; or in a PSD Class II or Class III area. EPA review and approval would be required before such an expansion is undertaken. We assume that such approval could be obtained as long as the resultant emissions increase is consistent with the nonattainment provisions of the 1977 Amendments.

c. Expansion at Non-Reverberatory Smelters

The four non-reverberatory smelters (Inspiration, Hidalgo, Anaconda, and Garfield) could increase their capacity after some investment in production equipment (mainly oxygen plants for oxygen enrichment) and pollution control equipment (upgrading of acid plants to NSPS calibre at Anaconda and Garfield).

Our order-of-magnitude estimates of the expansion potential at each of these smelters is as follows:

- Inspiration: This smelter has had operating problems with the electric furnace and has not operated at its rated capacity on a sustained basis. Our understanding is that these operating problems have been solved. The smelter employs NSPS calibre production and pollution control technology. Our estimate of the near-term capacity expansion potential is a maximum of 10 percent (15,000 tons/year).

- Anaconda: The Anaconda electric furnace has started up recently and has also not operated on a sustained basis. The smelter requires upgraded and expanded acid plant capacity before it is a NSPS smelter. Our estimate of the near-term expansion potential, after the noted pollution control investment, is a maximum of 10 percent (25,000 tons/year).

- Hidalgo: This Outokumpu flash smelter has started up recently and has not operated at the rated capacity on a sustained basis. In principle, an Outokumpu flash smelter can increase its capacity by oxygen enrichment of furnace gases. We estimate that Hidalgo's capacity could be increased by about 30 percent (30,000 tons/year) if oxygen enrichment is used.

- Garfield: This Noranda smelter is being started up. In principle a Noranda smelter can increase its capacity by oxygen enrichment of furnace gases. We estimate that Garfield's capacity could be increased by about 20 percent (50,000 tons/year) in this fashion. The smelter would have to upgrade its acid plant to NSPS calibre before this expansion is possible.

In total, these smelters have a near-term capacity expansion potential of about 120,000 short tons per year. It is difficult to estimate precisely when (and if) this capacity increment would be realized. The NSO has not yet been used, and, in two cases, expansion is contingent on additional pollution control investment. For the purpose of sensitivity analysis, we assume that each of these smelters will expand as indicated by 1981.

Other smelters might convert from reverberatory furnaces to alternative smelting technologies. Were this to happen, each converted source would qualify as an NSPS smelter; in addition, the conversion itself would allow major capacity increments within the RACT emissions limitation. We do not expect conversions to be complete before 1985 primarily because conversions require five to seven years from planning through sustained production.

In addition, the economics of conversion are not currently favorable. The economic criteria for replacement of existing technology with a competing technology of the same scale is that the annualized cost (annualized capital plus O&M) of the competitor is less than the variable cost of existing technology. In 1974 dollars, the annualized cost of flash, electric, and Noranda smelters ranges between 13 and 17¢/lb. of blister copper for standard size smelters (100,000 short tons/year). The variable costs of existing reverberatory furnace smelters range between 6 and 8 ¢/lb.[7]

d. Reverberatory Furnace Smelters

The traditional approach to incremental capacity expansion at reverberatory smelters was (1) to increase throughput by improving materials handling techniques, (2) to add additional furnaces, roasters, and converters, and (3) to increase the capabilities of individual pieces of process equipment, generally through reconstruction[8]. These straightforward techniques are no longer permitted because they would lead to increased emissions. A smelter cannot, for example, simply add a new converter (controlled to NSPS standards) if the new converter's emissions would not be offset elsewhere at the source. The addition of a new reverberatory furnace would, likewise, by illegal even if the smelter were processing impure concentrates. Improvements in materials handling, while reducing costs, cannot be realized as capacity expansions unless some means is found to avoid increasing smelter emissions.

The use of these methods is constrained by numerous environmental regulations (see Chapter IX). Those of most importance are:

- emissions at the source cannot increase; and
- all new and reconstructed equipment must meet New Source Performance Standards.

Because emissions at the source cannot increase, the modification provisions have no additional implications for the legality and expansion of capacity at reverberatroy furnace smelters.

The only relevant options in the context of the emissions limitation are those that increase capacity without increasing emissions. In the remainder of this section, we examine specific expansion techniques which are technically available to industry. The alternatives are[9]:

- installing fluid bed roasters at green charge smelters;
- converting an existing single acid plant to a double acid plant and, simultaneously, altering existing production equipment to increase throughput.

- increasing the reverberatory furnace smelting rate by 20 percent using preheated or oxygen enriched combustion air; and
- converting multi-hearth roasters to fluid bed roasters;
- gas blending.

The first option would be available for the four green charge smelters. Acid plant conversion is applicable to five reverberatory smelters. Oxygen enrichment is potentially applicable to all eleven reverberatory furnace smelters, including White Pine. With the possible exception of fluid bed roasters, there is no question that these expansion techniques are consistent with current environmental regulations. The issue is whether these routes are viable from the viewpoint of smelter management.

An expansion at RACT smelters of about 50 percent is possible by changing from green charge smelting to calcine smelting. The fluid bed roasters required under this approach would be controlled by double acid plants. Because calcines are smelted, reverb emissions per ton of charge would decrease, permitting an increase in smelting rate without increasing emissions. The 50 percent increase is calculated from the fact that typical green charge reverbs require 6 MMBtu of fuel per ton of charge, whereas, calcine charge reverbs require about 4 MMBtu/ton of charge. In order to achieve this capacity increase, significant alterations would be necessary in materials handling ahead of the roasters, significant changes in the reverbs to process calcines and to allow for proper stag/matte separation, and perhaps additional converter capacity. Such alterations might constitute a "reconstruction" of the reverb since the cost of these alterations could easily exceed 50 percent of the cost of a brand new facility. If so, NSPS would apply to the reverb. Such an occurrence would make this avenue of expansion infeasible.

Even if the reverb would not be considered to have undergone a "reconstruction", it is debatable whether industry would utilize this approach for capacity expansion. Some of the copper companies with experience with fluid bed roasters consider them to be unreliable and requiring a high degree of maintenance. In the United States, there are four green charge smelters would could utilize this approach. However, two of these belong to companies who already have poor operating experience with such roasters. More important, such an alteration would seem to commit the smelter to the indefinite future use of reverb smelting. In view of the 1988 requirements of the Act, a decision in favor of roast-reverb smelting would put the smelter in the risky position of assuming that cost-effective weak gas scrubbing techniques will becom available by 1988. Alternative assumptions under which such a decision could be made are even more uncertain; e.g., that the investment could be recouped before 1988 or that the requirements of the Act will be modified by the Congress before 1988. It, therefore, appears to us that that expansion plan, even if permitted by EPA, would not be employed by domestic smelters.

The second approach would be to convert single absorption acid plants to double absorption. This would provide a quantum of reduced emissions that could be used to allow an equivalent increase in emissions from production equipment. However, this approach only allows for a 6 to 7 percent increase in capacity. We believe that this capacity increment is too small to interest most smelters.

The third approach would be to use oxygen enrichment or preheating of combustion air to increase the smelting rate. The smelting rate could increase by 20 percent and reverberatory furnace emissions would increase by a similar amount. The ten Western reverberatory smelters could not achieve a significant capacity increment by this approach because converter emissions could not be reduced sufficiently to achieve the necessary offset.

The three Asarco smelters using multiple-hearth roasters are not likely to convert to fluid bed roasters because of the nature of the charge materials handled by these smelters. Even if such a change were technically feasible, a capacity expansion is blocked because reduced emissions from new roasters cannot be used to offset an increase in emissions from existing reverbs.

Finally, gas blending (e.g., the blending of weak reverb or multi-hearth roaster gases with somewhat stronger, but viable, converter gases) is not a cost-effective approach. Acid plants at smelters using converter gases alone consume considerable fuel to compensate for the fluctuations in the strength and volume of converter gas. The blending of a much weaker stream from reverbs or multi-hearth roasters can only increase the fuel use in an acid plant and magnify the problems that currently occur with converter gases alone. Because of these operating problems, this approach has not usually been used. It was used on a temporary basis in Japan during a major smelter alteration. In the United States, attempts at gas blending at Ajo were quite unsuccessful inspite of the fact that DMA scrubbing was included for concentrating SO_2.

To summarize, we believe that the probability of capacity expansion at existing reverberatory furance smelters through 1985 is extremely low. The RACT emissions limitation and the NSPS do not preclude expansion per se. However, the few expansion routes that do remain are either uneconomic or technically dubious or both.

3. Specific Industry Capacity Growth Scenarios

The discussion in this Chapter has shown that small incremental expansions at existing smelter sites as a means of capacity expansion would have to be ruled out. Further, major new capacity is not likely to come on-stream before 1985. Meanwhile, minor relief can be expected via additional growth in hydrometallurgical processing, which is based on the exploitation of the relatively small oxide deposits, and possibly via expansion at the four non-reverberatory furnace smelters (Inspiration, Anaconda, Hidalgo, and Garfield) if they upgrade to NSPS caliber control technology.

Major increments in smelter capacity are possible after 1984, either via conversion of existing smelters to non-reverberatory technology or by the construction of new grassroots smelters. Finally, all smelters will have to move towards full compliance with the requirements of the Clean Air Act by 1988 or close down at that time or even earlier.

These possibilities may be explored more systematically as follows, by examining the various combinations or permutations of the available capacity expansion paths, recognizing that not every path is equally plausible.

The various paths can be listed as follows:

- Path A: All existing smelters will be in compliance by January 1, 1988.
- Path B: One or more of the existing smelters will be closed down sometime during this period, while all others will be in compliance by January 1, 1988.
- Path C: One or more new (grassroots) smelters will come on-stream during the period 1985-1987.
- Path D: Additional electrowinning capacity will be brought on-stream over this period (i.e., 1978-1987).
- Path E: Four non-reverberatory furnace smelters (Inspiration, Anaconda, Hidalgo, and Garfield) will increase their combined effective capacity by about 120,000 annual short tons of refined copper equivalent production (NSPS expansion).

It can be seen that Paths A and B are mutually exclusive (i.e., they are "pure" cases), while Paths C, D, and E are each (at least on the face of it) non-conflicting with either Path A or with Path B. Hence, the following sixteen (16) combinations of paths appear, in principle, possible:

A
B
AC
AD
AE
ACD
ACE
ADE
ACDE
BC
BD
BE
BCD
BCE
BDE
BCDE

From among these sixteen (16) alternative combinations through which domestic primary smelter capacity might effectively expand (change) over roughly the next decade, we have selected two as the most plausible for the purpose of economic impact analysis (AD and BD), which, respectively, are labeled "Constrained Capacity" and "Reduced Capacity." These two basic scenarios, plus other less plausible scenarios, are defined as follows:

a. Constrained Capacity

This scenario assumes that none of the existing smelters will shutdown; all smelters currently employing reverberatory furnaces will make progress towards compliance by January 1, 1988, and that the bulk of the smelter conversion costs would be incurred during the second NSO period (i.e., 1984-1987); and that no new (greenfield) smelter capacity will be coming on-stream during this period, and only marginal electrowinning capacity is expected to be introduced over the five-year period, 1983-1987.

b. Reduced Capacity

This scenario, which is the more severe, assumes that three smelters (Phelps Dodge-Douglas, Kennecott-McGill, and Asarco-Tacoma or an equivalent smelter) will close down in 1983, for various reasons. These three smelters have a combined capacity of 268,000 annual short tons of refined copper equivalent production (i.e., Douglas, 90,000; McGill, 78,000; and Tacoma, 100,000 annual short tons). As under the Constrained Capacity scenario, no new (greenfield) smelter capacity will be coming on-stream during this period, and only marginal electrowinning capacity is expected to be introduced during the five-year period, 1983-1987.

c. Sensitivity Analysis Scenarios

These cover the following options:

- NSPS Expansion: This scenario assumes that an expansion of 120,000 tons/year is possible at the four non-reverberatory smelters by 1981 by investing in pollution control (acid plant upgrading) and production equipment (mainly oxygen plants).
- Grassroots Expansion: This scenario assumes two new grassroots smelters will come on-stream, one in 1985, and the other in 1987, with capacities of 200,000 tons/year (each).
- Effect of SCS: This scenario assumes a 10 percent reduction of existing capacity because of the use of SCS.

d. Discussion

The NSPS expansion scenario has been termed a "sensitivity analysis" scenario because of a number of unknowns: a necessary improvement in the copper market; and a resolution of the uncertainties surrounding the NSO process under which such an expansion would take place.

Capacity expansion via grassroots smelters is also a "sensitivity analysis" scenario because of the following reasons. In order for new smelters to be ready and operating by 1985-1987, the decision to build would have to be made soon. An affirmative decision, however, is not likely, in view of the currently depressed market conditions facing the copper industry and increasing price competition from abroad, even if some improvement in these conditions were expected soon. Second, even ignoring these factors, the timing and magnitude of investments in new smelters are not, in reality, likely to remain completely independent of compliance assumptions and other events affecting the industry.

The capital investment for a 200,000 tons/year smelter and associated mining, milling, and refining facilities will be about a billion dollars. The scale of such investments, even if reduced by some margin, is sizeable for any given individual firm. This is not to say that a new entrant into the copper industry (e.g., an oil company) or one of the present primary copper producers will not undertake investments of this magnitude. Alternatively, a group of firms may invest jointly. Since we have also assumed that the present firms make steady progress towards compliance and are in compliance by January 1, 1988, sizeable smelter conversion costs would be incurred by these firms during 1984-1987. In view of these costs, it would be less likely for these firms, in general, also to make major investments in new smelters at the same time.

The untried NSO process, capital requirements for major smelter conversion, or for grassroots smelters, the current depressed condition of the copper market and increasing price competition from abroad, etc., introduce complexities which stand in the way of any unique capacity growth scenario. The discussion in this section has delineated central tendencies or main directions, keeping in mind that exceptions may and do occur.

CHAPTER X

NOTES

1. The United States copper smelters started the installation of pollution control equipment shortly after the passage of the 1970 Clean Air Act Amendments. We chose the 1974 to 1987 period as the impact analysis period with 1974 as the base year. This approach therefore emphasizes future impacts without altogether ignoring the past. The effect of pre-1974 expenditures is felt during the impact analysis period in the form of annual fixed costs. (See Table XII-3).

2. J. C. Mathews, et. al., "SO_2 Control Processes for Nonferrous Smelters" January 1976. PB 251 409. This reference states that "the cost profile, both capital and operating, is not a total confirmation of the cost of providing an overall SO_2 control system, but rather an order-of-magnitude indication of the "grassroots" costs of installing a particular control system".

3. Development Document for Interim Final Effluent Limitations Guidelines and Proposed New Source Performance Standards--Primary Copper Smelting and Refining EPA 440/1-75/032-b February 1975.

4. As pointed out in Chapter IX, the RACT emissions limitation is calculated at capacity output. This mass limit does not, therfore, constrain the use of existing capacity; the problem is that emissions of this magnitude would often lead to violations of ambient air quality standards.

5. The assumptions used in the model were: Uncaptured fugitive rate - 400 lb/hr SO_2 EPA valley model; E or F stability, $u = 2.5$ mps, 22.5° sector average or EPA PTDIS model C or D stability, $u = 5$ mps.

6. For example, the Garfield smelter utilizes the Noranda process but retains the separate converting step to prevent the carry-over of bismuth to blister copper.

7. Environmental Considerations of Selected Energy Conserving Manufacturing Process Options, Vol. XIV, EPA-600/7-76-034n. December 1976.

8. The remaining possibility, increasing the copper content of the feed materials, has reached its technological limit as discussed in Chapter VI.

9. Weak gas scrubbing is ignored because it is expensive.

XI. METHODOLOGY FOR IMPACT ANALYSIS

A. INTRODUCTION

The purpose of this chapter is to describe, in general terms, the methodology used to translate the direct capacity and cost effects (see Chapter X) into changes in all pertinent economic variables, such as prices, output, consumption, employment and international trade. A detailed description of the methodology, prepared for the technical specialist, is presented in the Technical Appendix.

Economic impacts are typically measured as differences from a set of baseline forecasts. The baseline forecasts trace out the values that the pertinent economic variables would take, over a period of time, in the absence of a regulation. With a given regulation, the increased costs of production due to compliance cause these same economic variables to take new values, away from baseline conditions. The differences are attributed to the regulation and provide measures of the economic impact. Other effects of the regulation, such as plant closures and community impacts, are typically considered specifically, after industry-wide impacts are assessed. Since, however, plant closures could affect industry's productive capacity, allowance must be made in the impact analysis methodology to assess the direct and indirect effects of compliance costs on the growth in the industry's productive capacity. In fact, a slowdown in the industry's productive capacity may lead to far more serious economic impacts than could be attributed to cost increases alone. This link between compliance costs and the growth in an industry's productive capacity, which is difficult to quantify and often missing in past economic impact studies, is extremely important to impact analysis.

It is important to note, again, that the costs of complying with a regulation defined narrowly to include both capital (fixed) costs and variable costs, are separate from and provide inputs into an economic impact analysis. As a result of costs of compliance, a firm's or industry's costs and production are affected. For example, if, in the short-term, only additional capital (fixed) costs are incurred, then the firm's (or industry's) average fixed cost and average total cost schedules (functions) will shift upward, but its marginal cost and average variable cost schedules will remain unaffected. Alternatively, if only the variable costs (operating and maintenance costs) are increased due to compliance, then the average total cost, average variable cost, and marginal cost schedules are shifted upward, with no change in the average fixed cost schedule. This case is perfectly analogous, in the short-run, to the case of a specific tax levied on a firm's or industry's output. In general, both fixed and variable costs increase because of compliance. Then, the average total cost, average variable cost, marginal cost and average fixed cost schedules all shift upward. One needs to consider the market structure, production technology, demand schedules and other factors within a unified framework to translate these shifts in cost into impact results.

The unified analytical framework can take the form of a "partial equilibrium" or a "general equilibrium" approach. In principle, a "partial equilibrium" approach would be appropriate if we are looking at an industry, where economic impacts are basically highly localized. On the other hand, a "general equilibrium" approach becomes more and more appropriate if the particular industry or group of industries in question would be expected to have a fairly widespread or sizeable effect on the economy as a whole.

Development and application of a model which provides a unified analytical framework is usually necessary for economic impact analysis. This is primarily because model building forces one to think clearly about and account for all the important interrelationships involved in a problem. Different classes of models can be constructed for purposes of forecasting or policy analysis, each involving a different degree of complexity and each presenting a different level of comprehension about the real world processes that are being modeled. With or without quantitative models, the basic analytical issue is to assess to what extent a regulation or set of regulations will influence a set of pertinent economic variables, at the national, industry and regional levels.

For impact analysis in this study, we have developed and used an econometric model of the United States copper industry. In general, an econometric model is a representation of the real world constructed in such a way that the response of the particular economic system under consideration, in this case the United States copper industry to external stimuli (external shocks) can be investigated under the equivalent of "laboratory conditions".

Econometric models attempt to capture causal (structural) relationships pertaining to a commodity, industry, market or economic system, in the form of a system of equations. An econometric model typically comprises behavioral equations, technical relations and accounting relationships. The model contains endogenous variables (e.g., prices, output, etc.) whose values are to be explained by the model and exogenous variables (e.g., compliance costs, macroeconomic activity levels, etc.) whose values are determined outside the model.

The model we have developed and used for impact analysis was designed and constructed after a careful review of alternative modeling approaches (e.g., time-series, process economics, industrial dynamics, optimization models) and following a close examination of existing models of the copper industry.

Typically, time-series (or purely statistical) models are not appropriate for impact analysis, basically because they require no knowledge of or concern for real world causal relationships. Process models, which basically concentrate on the industrial production process, are quite useful for quantifying in detail how compliance costs affect production costs; however, in such models, market dynamics receive little emphasis (alternatively, it is difficult to fully incorporate market dynamics into such models).

These same observations also hold for optimization models (i.e., a variety of mathematical programming models, such as linear programming, etc.). These models, which can require quite extensive process economics and technical data, provide a powerful analytical approach for studying complex production processes (e.g., chemicals and petrochemicals, etc.) and could be useful for impact analysis if the emphasis is on assessing optimal (e.g., overall cost minimizing) response strategies on the part of a technologically complex industry faced with compliance costs affecting many products and production processes.

Next, the industrial dynamics approach (also known as "systems dynamics"), allows for explicit consideration of all known negative and positive feedback relationships, as well as time delays, in a system, and thus provides, on the surface at least, an ideal analytical framework for impact analysis. This modeling approach is, however, highly controversial, basically because it provides no safety check on the reasonableness of the individual relationships that make up the model. Further, the theoretical foundations of many of the relationships contained in such models have been found lacking.

Econometric models, by contrast, are essentially free of these two basic shortcomings generally associated with the industrial dynamics approach, and, in addition, allow for the consideration of many simultaneous real-world relationships within a unified, interdependent framework. We hence selected the econometric modeling approach for analyzing the economic impact of environmental regulations on the United States copper industry.

A survey of existing econometric models or analyses of the copper industry, reported in the Technical Appendix, led us immediately to the conclusion that their design did not permit an analysis of the economic impact of environmental regulations and, further, their structure could not be readily and satisfactorily modified for impact analysis. Moreover, they were basically static models which failed to capture the dynamics of the industry's investment in productive capacity and, further, the behavior of the producers with respect to their production and pricing decisions, in view of their existing productive capacity, their cost functions, and changes in their cost functions over time resulting from new capacity creation. In other words, these models failed to consider the relationship between market clearing, which is essentially a short-run process and the creation of new capacity, which represents the adjustment process between the short-run and the long-run. In short, the existing models uniformly displayed serious shortcomings in accurately and realistically dealing with the supply side of the market. Consequently, we attempted in our own work to rectify these deficiencies by constructing an econometric model of the United States copper industry, COPMOD I, which represents an integrated modeling effort, bringing together process engineering, econometrics and financial analysis.

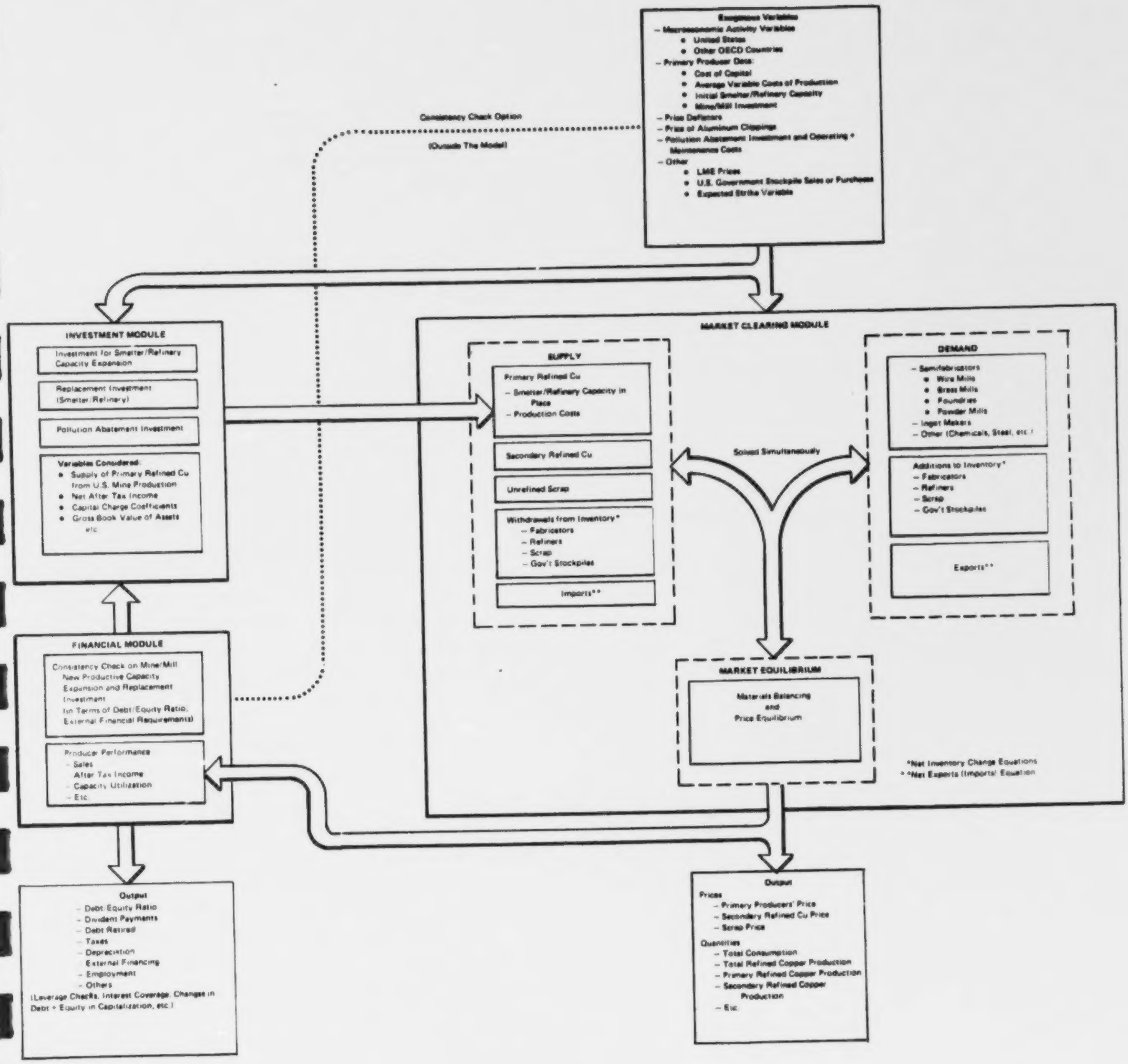
B. A NONTECHNICAL OVERVIEW OF THE MODEL

1. Summary

Figure XI-1 presents a simplified flow diagram of the structure of the econometric simulation and impact analysis model of the United States copper industry (COPMOD I) developed as part of this study for impact analysis purposes. The model is designed, estimated and programmed to simulate the industry's growth and evolution annually through 1987 under baseline conditions as well as under alternative environmental policy scenarios. COPMOD I considers within an interdependent framework, such variables as demand (paying attention to substitution from other materials such as aluminum) costs of production facing the producers, prices, investment and international trade. Costs of production are directly factored into the model through engineering cost functions so that technological developments as well as compliance costs affecting the industry can be readily assessed. Although the overall

FIGURE XI-1

SIMPLIFIED FLOW DIAGRAM OF THE ECONOMETRIC SIMULATION MODEL OF THE UNITED STATES COPPER INDUSTRY


Exogenous Variables
– Macroeconomic Activity Variables
• United States
• Other OECD Countries
– Primary Producer Data:
• Cost of Capital
• Average Variable Costs of Production
• Initial Smelter/Refinery Capacity
• Mine/Mill Investment
– Price Deflators
– Price of Aluminum Clippings
– Pollution Abatement Investment and Operating + Maintenance Costs
– Other
• LME Prices
• U.S. Government Stockpile Sales or Purchases
• Expected Strike Variable
Consistency Check Option
(Outside The Model)
INVESTMENT MODULE
Investment for Smelter/Refinery Capacity Expansion
Replacement Investment (Smelter/Refinery)
Pollution Abatement Investment
Variables Considered:
• Supply of Primary Refined Cu from U.S. Mine Production
• Net After Tax Income
• Capital Charge Coefficients
• Gross Book Value of Assets
etc
MARKET CLEARING MODULE
SUPPLY
Primary Refined Cu
– Smelter/Refinery Capacity in Place
– Production Costs
Secondary Refined Cu
Unrefined Scrap
Withdrawals from Inventory*
– Fabricators
– Refiners
– Scrap
– Gov't Stockpiles
Imports**
Solved Simultaneously
DEMAND
– Semifabricators
• Wire Mills
• Brass Mills
• Foundries
• Powder Mills
– Ingot Makers
– Other (Chemicals, Steel, etc.)
Additions to Inventory*
– Fabricators
– Refiners
– Scrap
– Gov't Stockpiles
Exports**
MARKET EQUILIBRIUM
Materials Balancing
and
Price Equilibrium
FINANCIAL MODULE
Consistency Check on Mine/Mill New Productive Capacity Expansion and Replacement Investment (in Terms of Debt/Equity Ratio, External Financial Requirements)
Producer Performance
– Sales
After Tax Income
– Capacity Utilization
– Etc
Output
– Debt Equity Ratio
– Divident Payments
– Debt Retired
– Taxes
– Depreciation
External Financing
– Employment
– Others
(Leverage Checks, Interest Coverage, Changes in Debt + Equity in Capitalization, etc.)
Output
Prices
– Primary Producers' Price
– Secondary Refined Cu Price
– Scrap Price
Quantities
– Total Consumption
– Total Refined Copper Production
– Primary Refined Copper Production
– Secondary Refined Copper Production
– Etc

*Net Inventory Change Equations

**Net Exports (Imports) Equation

model specifically deals with both the primary producers and with the secondary copper industry (and the interaction between the two sectors), its major focus is directed at the primary producers, with careful attention paid to their discretionary pricing and output behavior.

Given that inevitably a range of possible price and output outcomes can be expected in imperfectly competitive markets purely on theoretical grounds, we have chosen to "bound" the "solution space" of possible (and most plausible) outcomes analytically in our own modeling work. The pricing strategies or behavior utilized in the model identify, first, the "most likely" or "normal" behavior in a given year and, second, define reasonably solid bounds around that "most likely" or "normal" pricing behavior.

2. Model Components

The model contains three basic components (modules)

- The Market Clearing Module
- The Investment Module
- The Financial Module

Briefly, the Market Clearing Module considers for each year the different factors affecting copper prices, production levels, fluctuations in inventories, consumption levels, and international trade. These factors are considered simultaneously, by taking into account the costs of production of the primary producers, available smelter/refinery capacity, and the supply response of the secondary producers. The market is cleared in each year through materials balancing and price equilibrium equations. That is, the equations making up the Market Clearing Module analyze the industry by focusing on the sources of copper and uses of copper and how sources and uses are brought into equilibrium.

In the model, "market clearing" is achieved with a system of simultaneous equations. The module has two versions--linear and nonlinear. The first version in essence ignores capacity constraints and, in spite of its simplicity, is not very useful for this reason.

In the linear case, for instance, demand curves may intersect cost or supply functions beyond capacity, resulting in untenable forecasts of both prices and production levels. By contrast, the nonlinear version, among other things, is able to incorporate short-run capacity constraints by allowing production costs to rise steeply as "name plate" capacity is approached. Hence, the nonlinear version, which represents a more reasonable approximation of the variables and relationships being modeled, represents by far the more useful analytical system. All the model results presented in this report are based on the nonlinear version.

The Investment Module, based on the results of the Market Clearing Module plus other variables simulates for each future year the industry's expenditures on new plant and equipment and for replacement investment and thus estimates how smelter/refinery capacity changes each year.

The capital expenditures associated with both capacity expansion and replacement investment, along with other increases in fixed costs due to mining and milling investment, as well as pollution abatement investment, are translated into changes in the production costs of the primary producers. This module thus serves as a "hinge", connecting the solutions of the Market Clearing Module for successive years.

The Financial Module uses the results of both the Market Clearing Module and the Investment Module to analyze the financial performance of the primary producers as a group, in terms of such standard financial indicators as cash-flow (depreciation, after tax income, dividends, debt-retired, external financing required, etc.); flow of funds (source vs. uses); leverage checks; changes in debt and equity in capitalization, etc. Although this module of the model is not fully simultaneous with the other two modules, it is designed to permit an external check on the overall performance of the entire model. Once the model is solved for the entire forecast period (i.e., 1974-1985), external checks are performed on the model's results, focusing directly on the industry's overall financial performance. These external checks include an analysis of the exogenously specified mining and milling investment behavior in terms of various measures of profitability, given the price forecasts. Likewise, overall cash-flow and flow-of-funds (sources vs. uses) analyses are performed, by analyzing financial data computed directly from the model's results, as well as on the basis of detailed historical industry-wide and specific company-by-company financial data. Thus, for example, if these external checks indicate possible overinvestment at the mining and milling level, the exogenously specified mine and mill investment would be reduced until the results, judged by their financial implications, appear the most plausible.

3. Model Results

The Market Clearing Module yields forecasts for the following major variables, among others, which are jointly-determined:

- total consumption of refined copper and its equivalent
- changes in inventory stocks (additions, reductions), primary producers
- changes in inventory stocks (addition, reductions), semi-fabricators
- changes in invnetory stocks (additions, reductions), secondary refiners
- net international trade (net exports, net imports)
- production of primary refined copper by the domestic primary producers (from domestically mined copper, imported concentrates, plus scrap) sold basically at domestic primary producers' prices
- production of secondary refined copper from scrap sold on the "outside" market
- production of scrap copper which is used directly
- price of primary refined copper (domestic producers' price, in cents per pound)
- price of secondary refined copper sold on the "outside" market
- price of copper scrap

The following major variables are specified outside the Market Clearing Module and, hence, are exogenous to the model:

- Federal Reserve Board industrial production index for manufactured durable products
- industrial production index for manufactured durable products in other OECD countries

- LME copper price (varied over a wide range for sensitivity analysis)
- price of aluminum clippings (used as a surrogate for aluminum transaction prices, in order to gauge possible substitution of aluminum for copper)
- United States Government stockpile (net additions to or net sales from)
- average (unit) variable cost of production for the primary producers, at all levels of production (i.e., average variable cost function)
- average fixed costs of production for the primary producers, at all levels of production (i.e., average fixed cost function, from the Investment Module)
- beginning-of-year domestic primary copper smelter/refinery capacity (from the Investment Module)
- dummy variables for strikes and expected strikes

4. Microeconomic Considerations Incorporated Into the Model

The effect of a regulation on product price and quantity depends on industry pricing behavior. Industry pricing behavior, in turn, is conditioned by industry or market structure. Consequently, at least three issues need to be addressed: (a) what is the relationship between industry/market structure and industry pricing behavior, (b) how is the copper industry's structure and pricing behavior characterized, (c) how is the copper industry's pricing behavior handled in the model?

a. Industry/Market Structure and Pricing Behavior

Analysis of the structure of an industry/market requires the examination of three interrelated areas: (a) structure, (b) conduct (behavior), and (c) performance. The three areas or concepts are interrelated in that the structure of a market is generally understood to determine the conduct (i.e., pricing behavior) of the participants in the market, and the conduct, in turn, is believed to determine the performance (e.g., financial) of the participating firms.

Various criteria are typically used in defining the structure of an industry. The basic criteria are the existence and closeness of substitutes and the extent to which the participating firms in the industry take into account the reactions of competitors. The latter criterion is closely related to the number of firms in the industry and the degree of differentiation of the product.

The two polar extremes in the range of market structures are "perfect competition" and "monopoly".

"Perfect competition" is characterized by

- a very small number of firms (buyers and sellers) where each firm accounts for an extremely small share of the market;
- a homogeneous or standardized product is involved;
- the numerous buyers and sellers are well-informed about product quality and about each other's prices;
- the entry of new firms into the industry/market is free and easy (i.e., there are no "barriers to entry").

In such a situation, individual firms have no influence over the going market price; each firm is a "price taker" and decides only how much to produce and sell, under prevailing prices, given its cost structure. Each one firm acts atomistically, that is, it decides its level of output ignoring the others in the industry. Since the products of the firms are perfect substitutes for one another the price-elasticity of demand facing the individual firm in infinite (i.e., the demand function facing the firm is horizontal).

It is important to note that very few actual markets can meet the definition of perfect competition. Also, the word "competition" is used in a special sense. In the words of Oskar Morgenstern[1]

> Competition means struggle, fight, maneuvering, bluff, hiding information--and precisely that word is used to describe a situation in which no one has any influence on anything, where there is ni gain, ni perte, where everyone faces fixed conditions, given prices, and only has to adapt himself to them so as to attain an individual maximum which may even be zero as in the case of profits.

In contrast, in the case of a "monopoly", there is only one firm in the industry and there are no close substitutes for the product of the monopolist. The demand of the monopolist coincides with the industry demand, which has a finite price elasticity. Entry is blockaded.

Another market structure, "monopolistic competition" is defined by the case where there is a very large number of firms, but their product is somewhat differentiated. Hence, the demand facing the individual firm is not perfectly elastic (as is the case under "perfect competition") but its price elasticity is high due to the existence of the close substitutes produced by the other firms in the industry. Despite the existence of close substitutes, each firm acts atomistically ignoring the competitors' reactions because there are too many of them and each one would be very little affected by the actions of any other competitor.

Finally, another market structure is the "oligopolistic" market, meaning a market with "few sellers"[2]. Oligopolies can be of two types: when the products are fairly homogeneous or standard, we have a "pure oligopoly"; when the products are differentiated we have a "differentiated oligopoly". In the latter case the elasticity of the individual market demand is smaller than in the case of the pure or homogeneous oligopoly. Because an oligopolistic market is characterized by relatively few sellers who are conscious of their interdependence, they typically have some influence on market prices, however small. Since the number of firms is small, the selling price and output decisions or actions of any one firm will depend on and will affect the policies of its rivals. The oligopolist is like a person who is playing chess: before taking any action, he must consider the possible reactions on the part of his opponent and how to counter them.

Given that there is a very large number of possible reactions of competitors, the behavior of firms may assume various forms and their decisions may depend on the ease of entry and the time lag which they forecast to intervene between their own action and the rivals' reactions. Thus, there are various models of oligopolistic behavior, each based on different sets of assumptions on the reaction patterns of rivals. In oligopolistic markets, barriers to entry, determined by the size of investment required for a minimum efficient scale of operations, is typically not as easy as under perfect or monopolistic competition.

For an industry characterized as perfectly competitive, the industry supply curve (under the usual behavioral rule of profit maximization) is the horizontal summation of the marginal cost curves of individual firms. Thus a unique, deterministic solution is obtained for price and output at the intersection of the supply and demand curves.

For a monopolist, the output and price, again, is uniquely determined by the intersection of the marginal cost, MC, and marginal revenue, MR, curves. These points can be readily verified by consulting an elementary text on microeconomics.

In oligopolistic markets, by contrast, microeconomic theory no longer supports the concept or use of a supply function. Deterministic market solutions, based upon the supply and demand functions alone, are no longer possible and a range of possible price and output solutions can be expected on purely theoretical grounds.

b. Copper Industry Structure and Pricing Behavior

As indicated before (Chapter III - The Structure of the United States Copper Industry) the domestic copper industry can be segmented into "primary" and "secondary" sectors, for analytical purposes, on the basis of the pricing behavior of the firms on the sellers' side. By this criterion, the primary sector consists of firms which sell the bulk of their refined copper output (mostly from mined copper but also including some refined from scrap) on the basis of a commonly-followed domestic producers' price. Firms in the secondary sector, on the other hand, are those which sell their copper output regardless of its form (i.e., whether refined or scrap) and regardless of its origin (i.e., whether processed from mined copper-- from domestic or foreign source-- or refined from scrap) on the basis of one or several "outside market" prices.

The "outside market" in the United States consists of a subset of secondary or custom smelters/refiners selling on the "outside" market, the producers/sellers of non-refined scrap, and the merchants who import copper-containing materials in various forms for toll smelting/refining and for sale on the outside market. In the model, we have assumed that these sectors of the "outside market" are "workably" competitive[3].

Within the United States copper industry, the primary producers may be labeled oligopolistic based on the fact that there are only about eleven such producers, vertically integrated to varying degrees. Another factor which would support such a classification is the existence of the producer price for copper as separate from a world "market" price for copper, which is represented basically by the LME copper price. The historical relationship between the domestic primary producers' prices and the LME prices (i.e., the existence of a two-price system for copper) has been discussed at length in Chapter VIII--Prices. Also, earlier, the relationship bewteen the domestic copper industry and the world copper industry was discussed in Chapter V--Relationship to the World Industry.

c. How Pricing Behavior is Treated in the Model

Such characteristics of industry structure notwithstanding, there is no consensus view of pricing in the domestic copper industry. Some respected researchers (e.g., Charles River Associates, Inc.) view the industry as competitive. Despite the small number of domestic primary producers, these researchers believe that the international market for copper, competition from secondary suppliers and the lack of tariff barriers force domestic producers to act like pure competitors. Others have viewed the industry as being monopolistic and still others have stressed the apparent indeterminacy of pricing patterns.

The adherents to the "perfect competition" model may have a point in terms of how the world copper market seems to operate during periods periods of economic downturn (i.e., during demand slack periods). But even here it represents an oversimplification, in view of the continued prevalence of the two-price system during such periods. In general, we do not believe such a pricing model, despite its analytical convenience, realistically comes to grips with the vexing analytical problem before us. We further reject the "monopoly" pricing model as simply not credible at all, based on plenty of available evidence. Only under extreme demand-crunch conditions does the industry appear to have moved, however slightly, in the direction of monopoly pricing. Based on our historical model simulations, we cannot find any evidence of a consistent tendency toward monopoly pricing.

In modeling the behavior of the primary producers, we have chosen a "parametric" approach where we define several pricing strategies in order to define the parameters or outer boundaries of possible outcomes and assess the sensitivity of the market results to variations in behavioral parameters. The following three points define these parameteric solutions:

- Average variable cost pricing (AVC = AR, where AVC is the average variable cost schedule and AR is the net demand schedule facing the primary producers): This defines general pricing behavior mostly during demand-slack periods when member firms tend to operate well below designed capacity and when they are particularly susceptible to pricing discipline breakdowns;

- Full cost pricing (ATC = AR, where AR is as defined and ATC is the average total cost schedule facing the primary producers): This represents the industry's "normal" pricing behavior; and

- Implicit monopolistic pricing (obtained via the intersection of the marginal cost, MC and marginal revenue, MR, schedules): This represents the industry's "theroetically possible" pricing tendency during extreme "demand-crunch" periods.

As noted earlier, the first and third solution points provide the most plausible theoretical boundaries of the expected market solutions with respect to prices and output. Another possible solution point is given at MC = AR, since under "normal" market conditions there would be little micro-theoretical reason for firms to produce to the right of the intersection of the MC and AR schedules (i.e., in this region, marginal cost would exceed price). However, such a solution point, while reasonable from a theoretical standpoint, appears to have very little, if any, practical currency in terms of the actual pricing decisions of the firms in the industry and would, at any rate, provide only a marginal improvement over the range of solutions that can be expected.

The "normal" pricing "rule" used by the primary producers can best be characterized as "full cost pricing"[4] (or "average cost pricing"), including a target or desired rate of return on investment. By this formulation, price is set equal to average total cost, ATC, where average total cost includes average operating costs (i.e., average variable costs) plus average fixed costs which include a target or desired rate of return on investment. The desired or target rate of return on investment can be thought of as that return required to maintain and expand the capital stock of the primary producers[5]. In a public utility sense, that target rate of return is the "fair rate of return" required to attract sufficient new capital[6].

While "full cost pricing" appears to realistically characterize the pricing strategy of an oligopolistic firm or group of firms in "normal" years, with "normal" demand and supply conditions, there are going to be short-run conditions that deviate such a pricing strategy from its target. For the primary producers, such developments as a collapse in world demand, international competition, or competition from secondary supplies could and do prevent the primary producers from realizing the expected "full cost pricing" strategy. Consistent with this view, the lower bound on price in a given year has been identified as the equality of price and average variable costs (AVC). At this point, the unit price is covering average operating costs alone without any fixed cost coverage. While this lower bound reflects a possibility in the short-run, a firm or group of firms cannot price at this lower bound for very long without going bankrupt. Such a situation would occur during a demand-slack period[7].

The short-run upper bound upon price identified for our analysis is the "monopolistic" point determined by the intersection of primary sector's marginal cost and marginal revenue curves. Of course, this is a theoretical upper bound only in the hypothetical sense that perfect collusion exists, that profit sharing agreements were operative and worked perfectly and that the marginal cost curve fully articulates this collusive behavior. As a matter of fact, the simulation results of the model indicate that the "monopolistic" price solutions are considerably above the "full cost pricing" solution in most years. At any rate, it was not expected that the primary producers would gravitate consistently to a short-run collusive monopolistic price solution, both because of legal reasons and because of the real concern about the threat of long-run substitution from aluminum. However, this upper bound has been included for theoretical reasons, if not for its practical significance.

5. Treatment of Pollution Abatement Expenditures in the Model for Impact Analysis Purposes

Pollution abatement expenditures are introduced into the model as follows. Average variable costs (i.e., the operating and maintenance costs) associated with pollution abatement are introduced directly by shifting-up the average variable cost function facing the primary producers. Pollution abatement capital expenditures, meanwhile, are introduced directly into the Investment Module, by year of expenditure (i.e., dollar outflow); these expenditures are annualized internally by the model through the use of capital charge coefficients. It should be noted, in this context, that the Investment Module separately keeps track, in a bookkeeping sense, of three different types of capital stock (i.e., gross book value of assets) and capital flows (i.e., annual capital charges or annual fixed costs): investments made before 1974, new investments made thereafter for productive capacity expansion and replacement, and pollution abatement investment. These three different investment streams are separately handled, annualized and then combined to determine, annually, total fixed costs facing the primary producers. These total fixed costs are next transformed into an average fixed cost function (i.e., unit fixed cost at all levels of production) which contains an expected rate of return on invested capital. This, combined with the average variable cost function (exogenous to the model, as defined above), yields the average total cost function (i.e., total unit cost of production, including both fixed and variable costs, at all levels of production) facing the domestic primary producers each year.

In short, the model is designed in such a way that both the cost and the capacity effects of environmental regulations on the United States copper industry can be readily measured annually over a period of years.

6. Simplified Demonstrations of How Cost and Capacity Change Due to Environmental Regulations Affect Prices and Production Levels

As mentioned above, the effects of environmental regulations on prices and production levels depend on the pricing behavior of the firms in an industry, which in turn is conditioned by the structure of the industry or the relevant market for the product in question. The response of a monopolist, for example, would be quite different from that of firms under perfect competition. It is necessary, therefore, to specify an appropriate microeconomic model of price determination, in order to deal effectively with the simultaneous or interdependent adjustment process in demand, supply (costs), and prices.

The precise effects of increased production costs due to environmental controls, ignoring for the moment capacity effects, depend upon the demand and supply elasticities of the firms in the industry. The greater the elasticity of demand (other things being equal), for example, the less price will rise as new costs are incurred. With negatively sloped demand curves, an upward shift in production costs would, in the general case, lead to an increased price and to a reduction in the number of units purchased (and, therefore, to a reduction in production). In general, whether and to what extent increased costs can be "passed on" depends on the demand and supply elasticities.

Economic impact analysis through the specification of such a unified microeconomic model of price-output determination is generally not a trivial problem analytically, in view of the fact that many market structures which exist in reality cannot be neatly categorized into the textbook polar cases of perfect competition and monopoly.

Also, short-run effects need to be analytically distinguished from long-run effects. Further, whether the industry is characterized as one having increasing returns to scale (i.e., a doubling of all inputs may lead to more than a doubling of output), constant returns to scale (i.e., a doubling of all inputs leads only to a doubling of output) or decreasing returns to scale (i.e., a doubling of all inputs may lead to less than a doubling of output) requires attention. Moreover, how industry structure in the rest of the world affects price-output determination in the industry domestically deserves emphasis. Finally, if the industry or market may include a number of submarkets, such as the workably competitive "outside" market in the case of the U.S. copper industry, the analysis becomes even more complicated, for example, as one attempts to trace through the interaction between the primary producers and the participants on the "outside" market in terms of their respective price-output determination behavior.

These analytical complications are ignored in the simplified demonstration given below to illustrate with the aid of graphs how cost and capacity changes due to environmental regulations affect prices and production levels. We assume average cost pricing and, in order to keep the graphical presentation at an intelligible level, we suppress all but the primary producers sector of the model. This necessarily distorts the precise way the model works, but, we feel, adequately communicates the main ideas. The graphical analysis first examines shorter-term effects and then looks at longer-term dynamic effects.

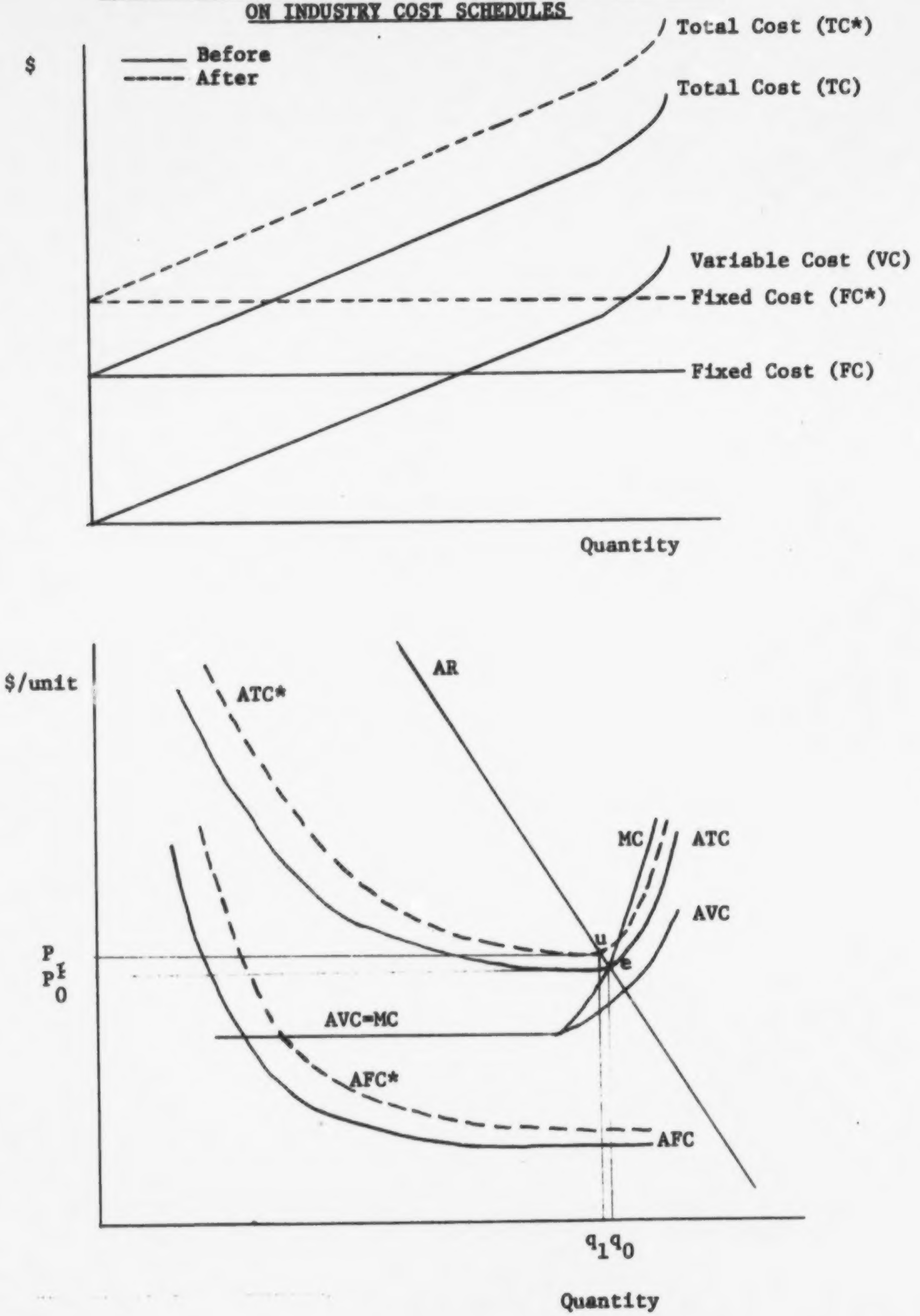
a. Short-run Effects

We start with the case where the existing capacity is fixed and there is no shift in the demand function facing the firms in the industry. We first consider the case where pollution control costs consist only of capital costs (i.e., investment in plant and equipment). This is shown in Figure XI-2A.

The short-run is typically defined as any time interval during which the existing productive capacity is, for all practical purpose, fixed. This varies from industry to industry. In the copper industry, for example, incremental smelter capacity expansion at existing sites can take place over a relatively short period of time, such as a year. However, it would take five-to-seven years for a minimum efficient size "greenfield" smelter to be brought on-stream. Hence, the "short-run" and "longer-run" designations

FIGURE XI-2A

EFFECTS OF POLLUTION CONTROL CAPITAL (FIXED) COSTS ON INDUSTRY COST SCHEDULES



used here refer, respectively, to time intervals defined with some flexibility (e.g., "short-run": at least a year; "longer-run": at least a few years).

A firm's or industry's cost functions show various relationships between costs and the level of output. Total fixed costs (FC) are the total obligations per period of time incurred for fixed inputs (capital charges, including the depreciation of buildings and equipment, property taxes, etc.). Since the quantity of the fixed inputs is fixed (by definition), the total fixed cost will be the same regardless of output. Total variable costs (VC) are the total costs incurred for variable inputs (e.g., labor, energy, etc.). They increase as the level of output increases, since larger output levels require larger inputs of the variable factors of production, which mean higher variable costs. Total costs (TC) are the sum of total fixed costs and total variable costs.

There are three average cost functions derived from these three aggregate cost functions, by dividing them by output. Thus, average fixed cost (AFC) is obtained by dividing total fixed cost (FC) by output, q (i.e., FC/q). The average variable cost (AVC) is total variable cost (VC) divided by output. The average total cost (ATC) is total cost (TC) divided by output. It should be noted that average total cost (ATC), as defined here, includes a rate of return on investment. Finally, the marginal cost (MC) is the addition to total cost resulting from the additional production of the last unit of output, given the existing capacity. These various cost schedules are depicted in Figure XI-2A as well as in the other accompanying figures.

Pollution control investment, appropriately annualized (see Chapter XII for a discussion), cause an upward shift in the aggregate fixed cost schedule facing the primary producers, as shown in the top graph. The effect of this, as shown in the bottom graph, is to shift upward (vertically) the primary producers' (industry) average fixed cost (AFC) and average total cost (ATC) schedules (functions). The magnitude of the upward shift is greater at lower levels of production, since the increase in fixed costs is spread over fewer units produced. The pre-compliance equilibrium price (p_o) and output (q_o) solution is given at point e. Post-compliance solution (p_1, q_1) is given at point u. Price is increased by ($p_1 - p_o$) cents/lb. and production is reduced by ($q_o - q_1$) short tons of refined copper equivalent. It should be noted that the average variable cost (AVC) and marginal cost (MC) schedules remain unaffected. The various cost functions rise precipitously as "nameplate" capacity is approached, consistent with the law of diminishing marginal returns (i.e., if equal increments of a factor input, such as labor or energy, are added when the quantities of other factor inputs, such as plant capacity, are held constant, the resulting increments of product will decrease beyond some point; that is, the marginal product of the input will diminish). As capacity is approached, each extra unit of output is obtained at higher cost.

Figure XI-2B examines the case where pollution control costs consist only of an increase in industry variable costs, resulting in an upward shift in the aggregate variable cost schedule. To simplify matters, it is assumed that pollution control-related variable costs vary linearly with total output. Consequently, the absolute magnitude of the upward shift in the industry variable cost schedule increases as output increases (top figure). The bottom figure shows how, as a result, the industry AVC and MC schedules shift upward. It can be seen that the upward shift in AVC, MC, and ATC is by a constant (i.e., X cents/lb) over all levels of output. This is perfectly analogous to the case of an excise tax levied on output (e.g., X cents/lb.). The industry AFC schedule remains unaffected. As before, the points e and u denote the "before" and "after" price-output solution points; $(p_1 - p_o)$ shows the increase in price, Δp, and $(q_o - q_1)$ shows the reduction in output, $-\Delta q$.

Finally, Figure XI-2C combines the results of Figures XI-2A and XI-2B. As a result of the upward shifts in both fixed cost (FC) and variable cost (VC) schedules, AFC, AVC, MC and ATC schedules all shift upward; this shift, however, is asymmetrical for the AFC and ATC schedules, reflecting the fact that (AFC* - ATC)/q increases as q (output) is reduced. The same holds true for (ATC* - ATC)/q; in the limit, the per unit upward shift in the ATC schedule approaches the per unit upward shift in AVC or MC (i.e., AVC* - AVC/q).

As before, the pre-compliance market equilibrium is at point e and post-compliance equilibrium at point u; correspondingly, p_1 and q_1 are the new price and quantity solution points.

b. Longer-run Effects

The longer-run, dynamic effects of pollution control capital and operating costs are shown in Figures XI-3A, XI-3B and XI-3C. In all three figures the top graph shows the "expected" normal longer-run industry adjustment process: (a) demand shifts out from AR_o to AR_1, and (b) industry productive capacity is no longer assumed constant but it is allowed to expand. Corresponding to capacity expansion, the relevant industry cost functions shift out to the right. The points o and u denote, respectively, the short-run and longer-run price-output solutions p_o q_o and p_1 q_1. It should be noted that p_1 is greater than p_o, reflecting the underlying assumption of an increasing cost industry (i.e., increases in output through the expansion of the existing productive capacity require higher costs, given the state of the available technology, due, in this case, mostly to the deteriorating ore grade).

The top graph in Figure XI-3A depicts what might be called generalized "baseline" conditions. Corresponding to the secular shift in demand and the expansion in productive capacity, output increases from q_o to q_1 and price increases from p_o to p_1. The bottom graph in Figure XI-3A, meanwhile, shows a case where the industry faced pollution control costs (both capital and variable) and where environmental regulations do

FIGURE XI-2B

EFFECTS OF POLLUTION CONTROL OPERATING (VARIABLE) COSTS ON INDUSTRY COST SCHEDULES

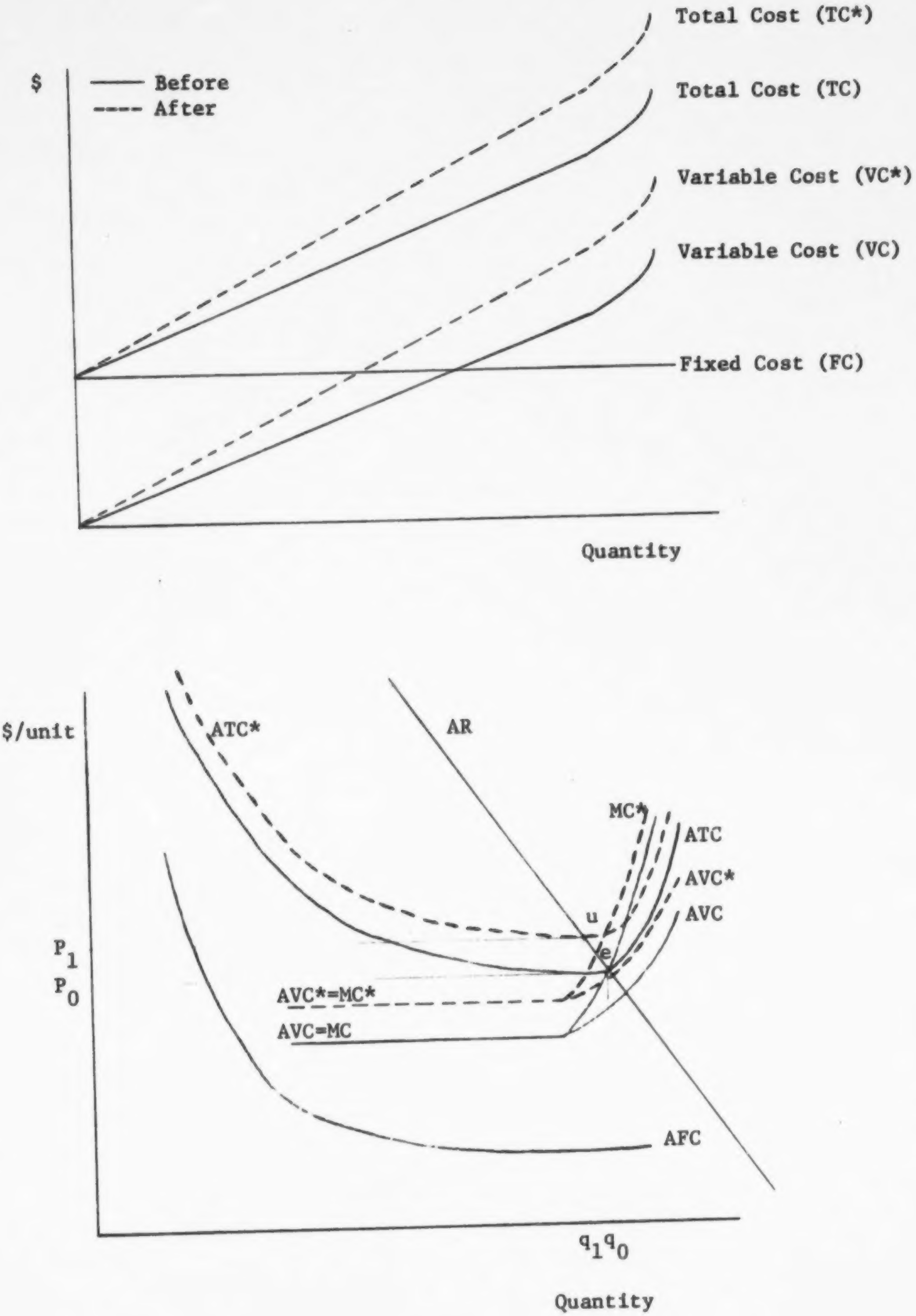


FIGURE XI-2C

EFFECTS OF POLLUTION CONTROL CAPITAL AND OPERATING COSTS ON INDUSTRY COST SCHEDULES

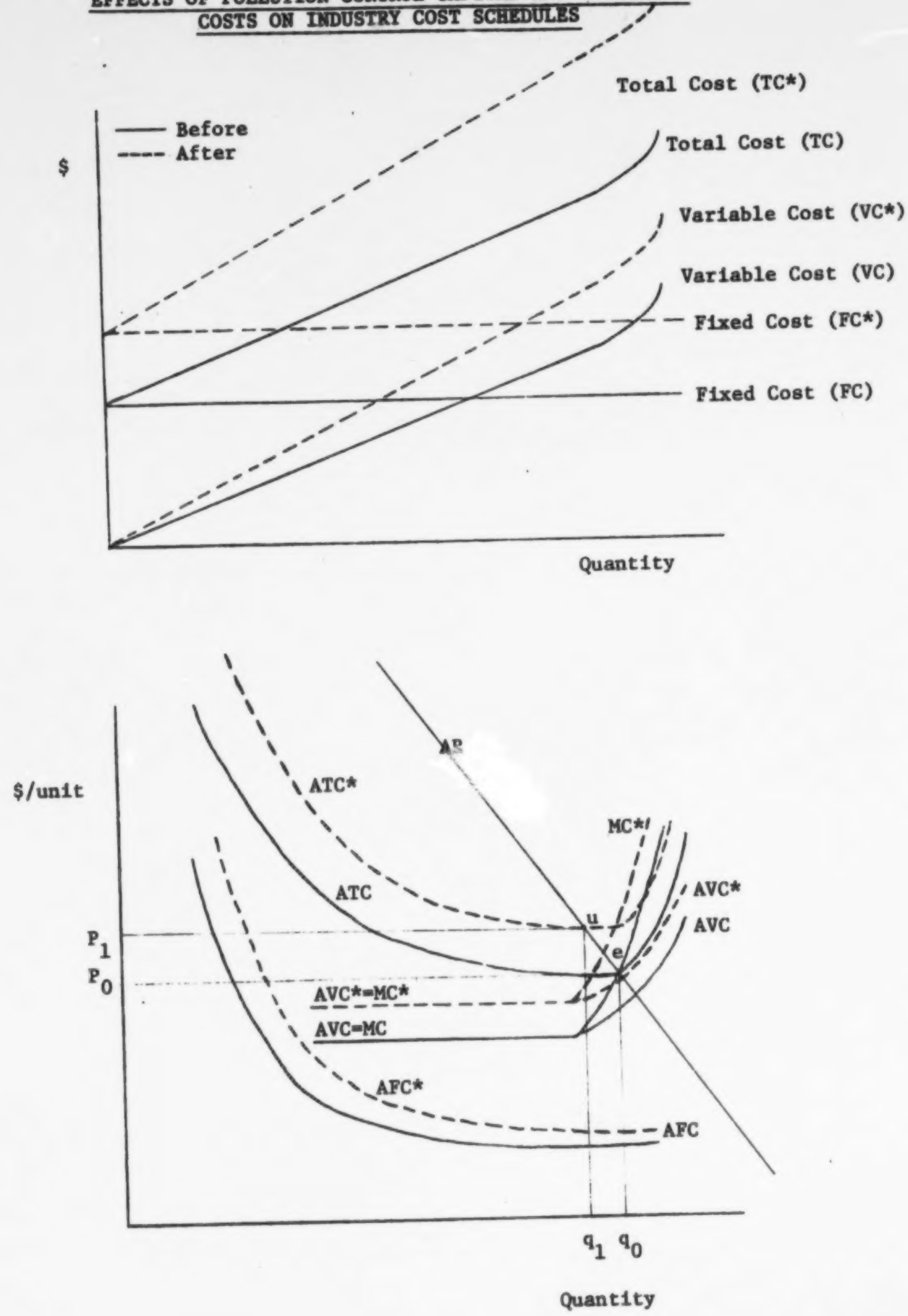


FIGURE XI-3A

EFFECTS OF POLLUTION CONTROL CAPITAL AND OPERATING COSTS ON INDUSTRY COST SCHEDULES, WITH CAPACITY EXPANSION AND SHIFT IN DEMAND

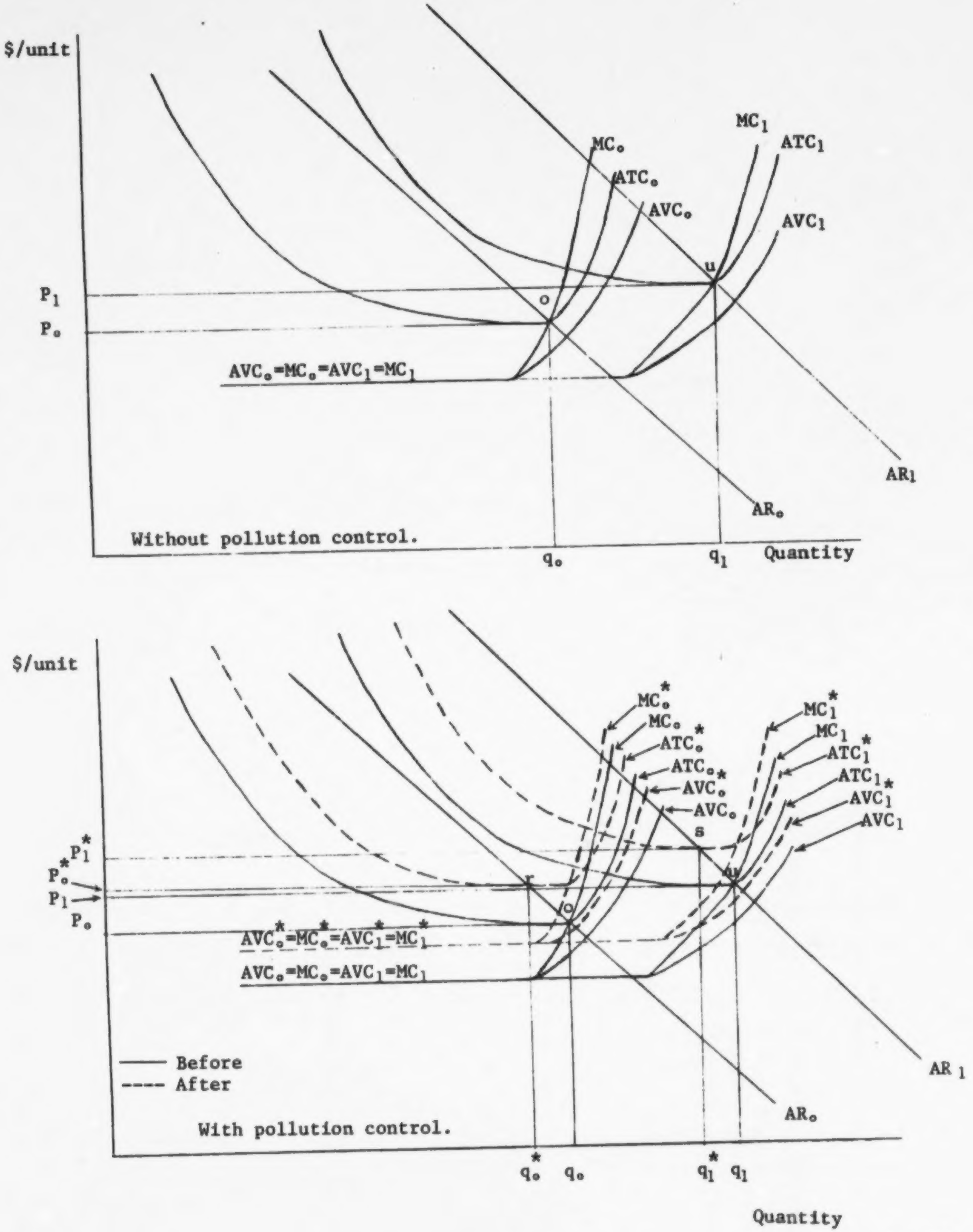


FIGURE XI-3B

EFFECTS OF POLLUTION CONTROL CAPITAL AND OPERATING COSTS ON INDUSTRY COST SCHEDULES, WITH CONSTRAINED CAPACITY AND SHIFT IN DEMAND

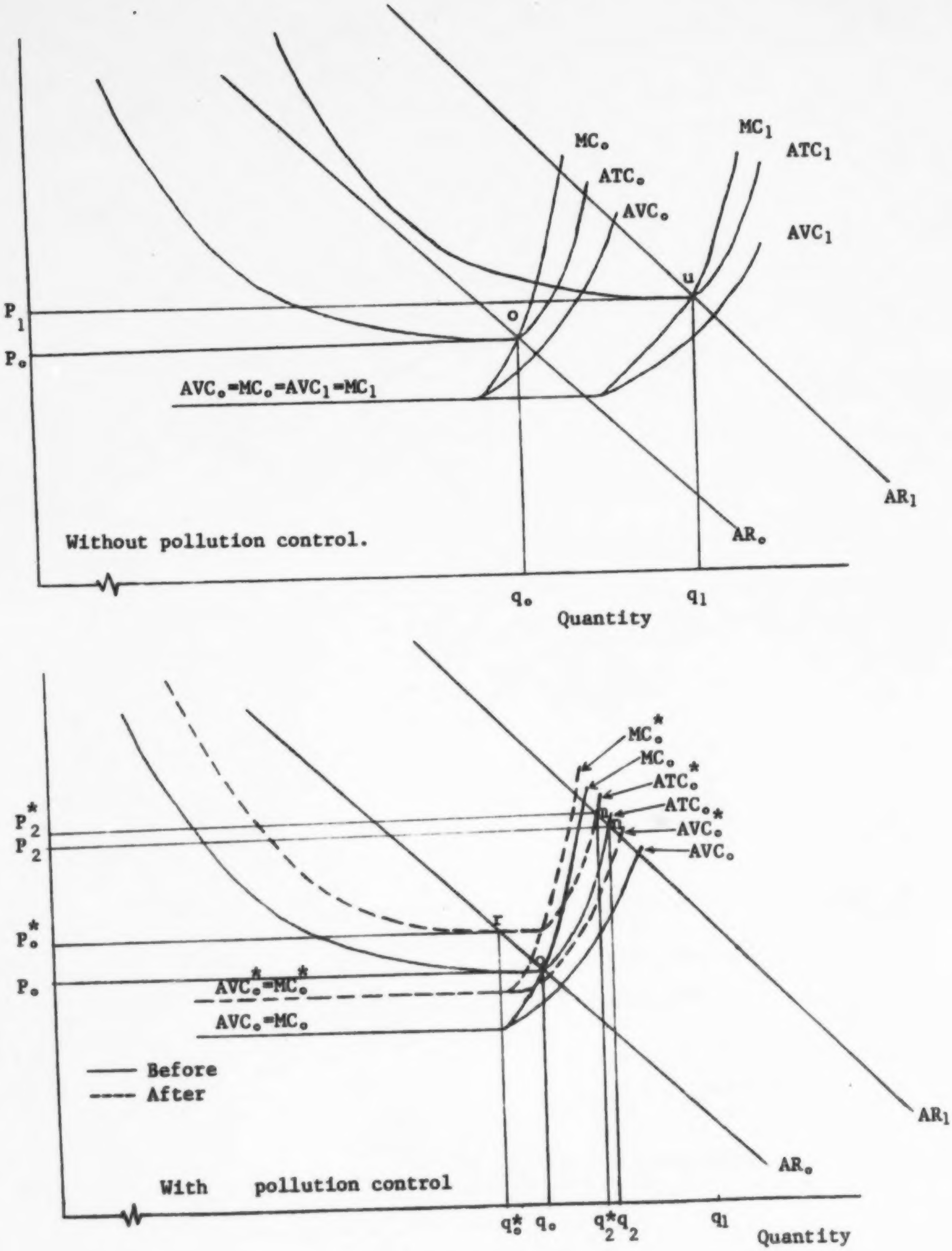
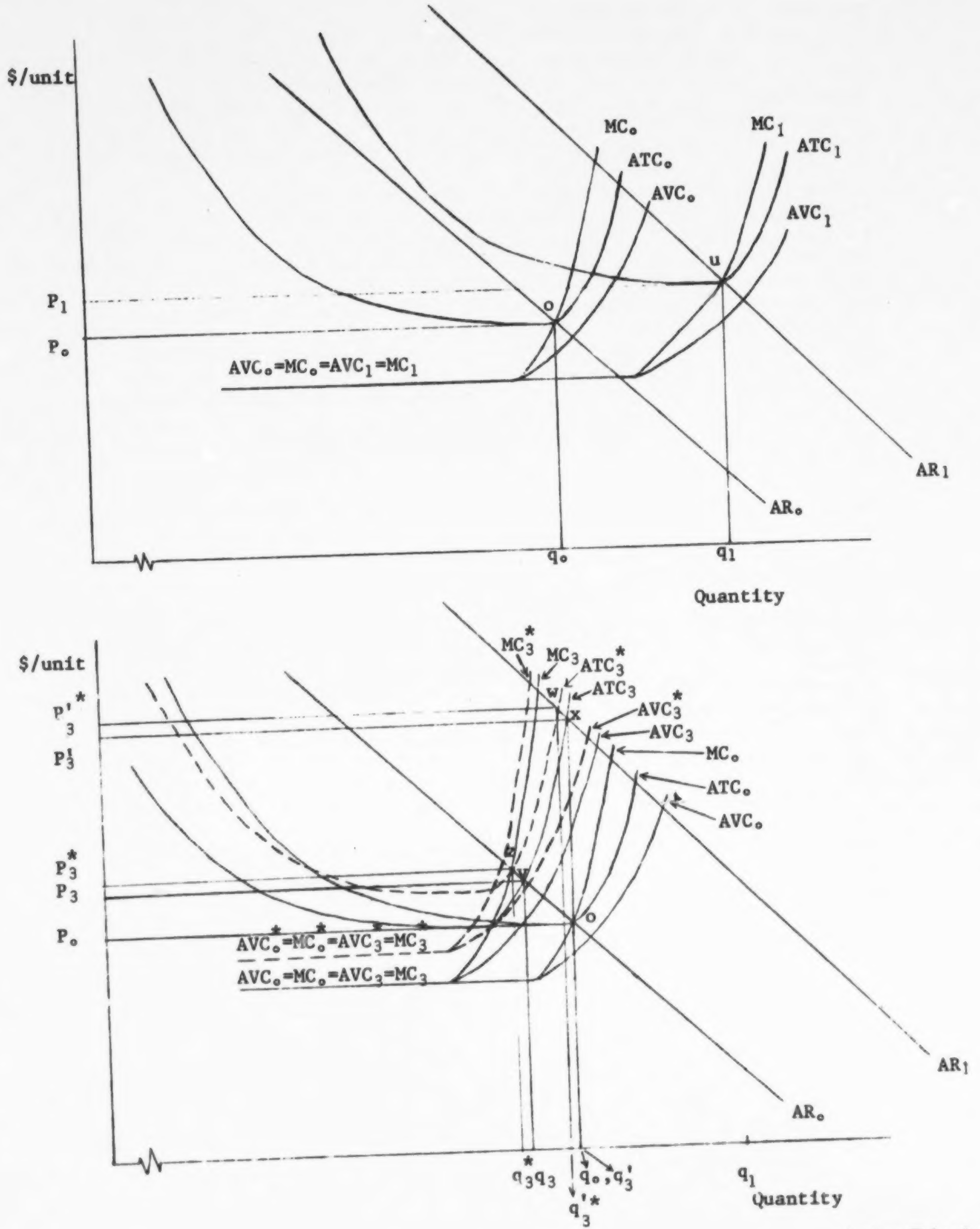


FIGURE XI-3C

EFFECTS OF POLLUTION CONTROL CAPITAL AND OPERATING COSTS ON INDUSTRY COST SCHEDULES, WITH REDUCED CAPACITY AND SHIFT IN DEMAND



$/unit
MC_o
ATC_o
AVC_o
MC_1
ATC_1
AVC_1
u
o
P_1
P_o
$AVC_o=MC_o=AVC_1=MC_1$
AR_1
AR_o
q_o
q_1
Quantity
$/unit
MC_3^*
MC_3
ATC_3^*
w
ATC_3
x
AVC_3^*
AVC_3
MC_o
ATC_o
AVC_o
$P_3'^*$
P_3'
P_3^*
P_3
P_o
$AVC_o^*=MC_o^*=AVC_3^*=MC_3^*$
$AVC_o=MC_o=AVC_3=MC_3$
o
AR_1
AR_o
q_3^* q_3
q_o, q_3'
$q_3'^*$
q_1
Quantity

not in any way constrain or impede capacity expansion. The short-run cost schedules are denoted by the subscript "o", the longer-run cost schedules by the subscript "1" and the altered cost schedules due to pollution control costs are identified by the superscript "*". The "generalized baseline" price-output solutions are given at point o (short-run) and u (longer-run); the after-compliance solutions are given at points r (short-run) and s (longer-run). In the longer-run, output is reduced from q_1 to q_1^* while the price increases from p_1 to p_1^*.

Figure XI-3B depicts the case where the implementation of the enivronmental regulations directly or effectively constrains expansion in the industry's productive capacity. With capacity constrained and an upward shift in the relevant cost functions due to pollution control, the new longer-run price-output solution is given at point m, where q_2^* amount is produced and the price has increased to p_2^* (note that $p_2^* > p_1^*$, where p_1^* is as given in Figure XI-3A). The solution given at point n (p_2, q_2) shows the unlikely longer-run case where capacity remains constrained by the environmental regulations but no compliance costs are incurred. It should be noted that this leads to only marginally improved conditions; this is because the effects of constraining growth in productive capacity readily predominate, compared to the effects of compliance costs taken by itself.

Finally, Figure XI-3C depicts a case where the implementation of the environmental regulations effectively leads to a reduction in the available productive capacity and where the industry is still faced with pollution control costs.

It is assumed in the bottom graph that the reduction in productive capacity does not alter the industry AFC, AVC, MC and ATC schedules; only,the AVC, MC and ATC schedules rise sooner. The post-compliance longer-term solution is given at point w, corresponding to p_3^* and q_3^*. The new "equilibrium" price, p_3^*, is higher than p_2^* (given in Figure 3B). Again, it can be seen that if environmental regulations effectively lead to a reduction in the available productive capacity while no compliance costs are incurred -- which is an unlikely event -- the impact results would not appear to be significantly different.

The illustrative microeconomic discussion given above is, on purpose, highly simplified, to convey via two-dimensional graphs the complex set of relationships and dynamic processes taking place over time that the model addresses systematically, comprehensively and in an internally consistent way. A condensed technical summary of the model is given next.

C. TECHNICAL SUMMARY OF THE MODEL

This section provides a condensed technical overview of the model, prepared for the technically-minded reader who may wish to consult the Technical Appendix for further detail.

The discussion is organized around the following major areas:

(1) Model specification: the Market Clearing Module, the Investment Module and their interaction;

(2) Final form of the estimated equations;

(3) Data sources and problems;

(4) Econometric estimation techniques used;

(5) Mathematical solution of the model; and,

(6) Basic differences between this and other econometric models of the copper industry

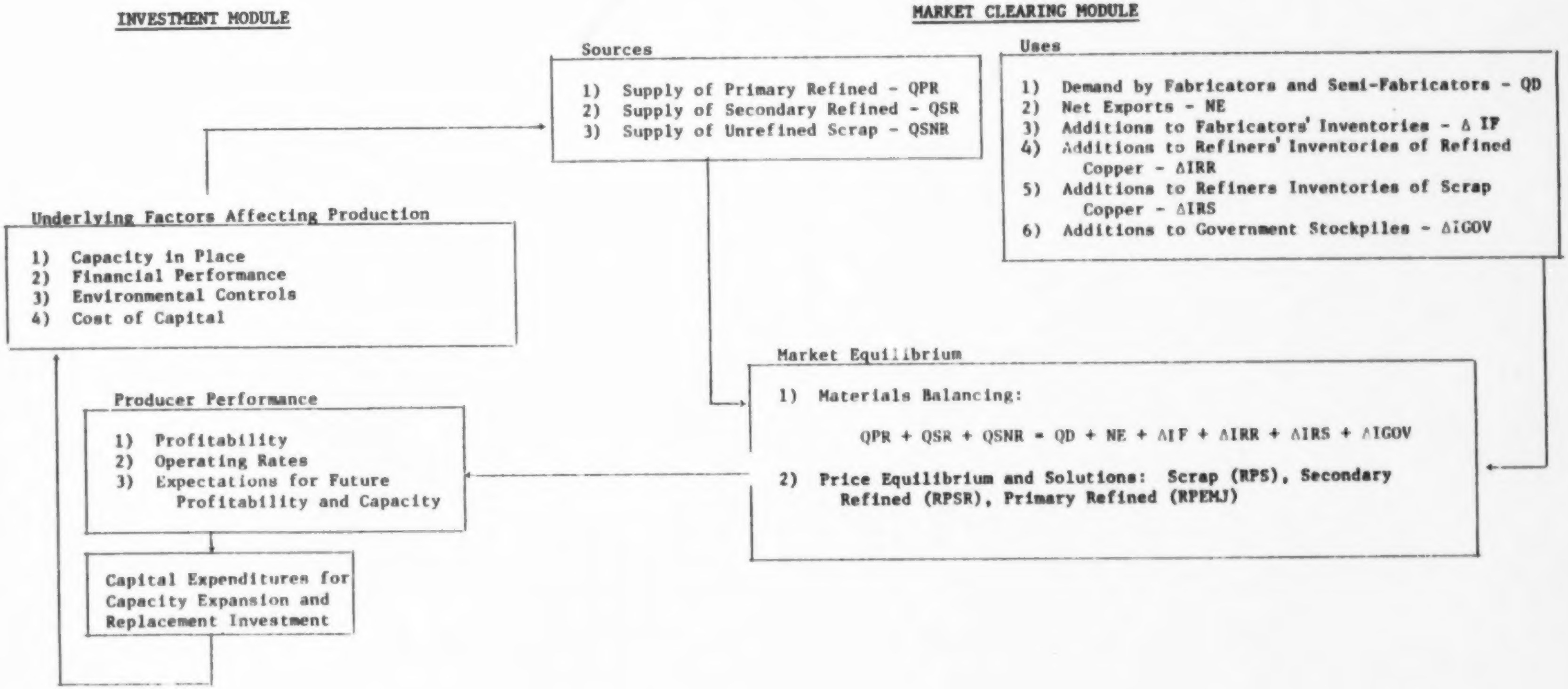
1. Model Specification: The Market Clearing Module, The Investment Module and Their Interaction

Two of the basic modules making up the model have been briefly introduced above. Figure XI-4 shows broadly the general outlines of the two modules and how they interact. The Market Clearing Module analyzes the industry by focusing on the sources of copper, and the relationships that indicate how the sources and uses are brought into market equilibrium in any given year. The endogenous variables measuring sources of copper include the supply of primary refined (QPR), the supply of secondary refined (QSR), and the supply of non-refined scrap (QSNR). The uses or demands for copper are six-fold: demand by fabricators and semi-fabricators (QD), net exports of copper (NE), additions to fabricator's inventories (ΔIF), additions of refined copper to primary refiners' inventories (ΔIRR), additions to scrap to secondary refiners' inventories (ΔIRS) and additions to government stockpiles (ΔIGOV). Of course, market equilibrium requires that materials balancing holds each year; Sources = Uses, or:

$$QPR + QSR + QSNR = QD + NE + \Delta IRR + \Delta IRS + \Delta IGOV$$

FIGURE XI-4

SIMPLIFIED DIAGRAM OF THE INTERACTION BETWEEN THE MARKET CLEARING MODULE AND THE INVESTMENT MODULE: A STATIC VIEW


INVESTMENT MODULE
MARKET CLEARING MODULE
Sources
1) Supply of Primary Refined - QPR
2) Supply of Secondary Refined - QSR
3) Supply of Unrefined Scrap - QSNR
Uses
1) Demand by Fabricators and Semi-Fabricators - QD
2) Net Exports - NE
3) Additions to Fabricators' Inventories - Δ IF
4) Additions to Refiners' Inventories of Refined Copper - ΔIRR
5) Additions to Refiners Inventories of Scrap Copper - ΔIRS
6) Additions to Government Stockpiles - ΔIGOV
Underlying Factors Affecting Production
1) Capacity in Place
2) Financial Performance
3) Environmental Controls
4) Cost of Capital
Market Equilibrium
1) Materials Balancing:
QPR + QSR + QSNR = QD + NE + ΔIF + ΔIRR + ΔIRS + ΔIGOV
2) Price Equilibrium and Solutions: Scrap (RPS), Secondary Refined (RPSR), Primary Refined (RPEMJ)
Producer Performance
1) Profitability
2) Operating Rates
3) Expectations for Future Profitability and Capacity
Capital Expenditures for Capacity Expansion and Replacement Investment

Further, the real price of scrap (RPS), secondary refined copper (RPSR) and primary producer copper (RPEMJ) must adjust to clear the market.

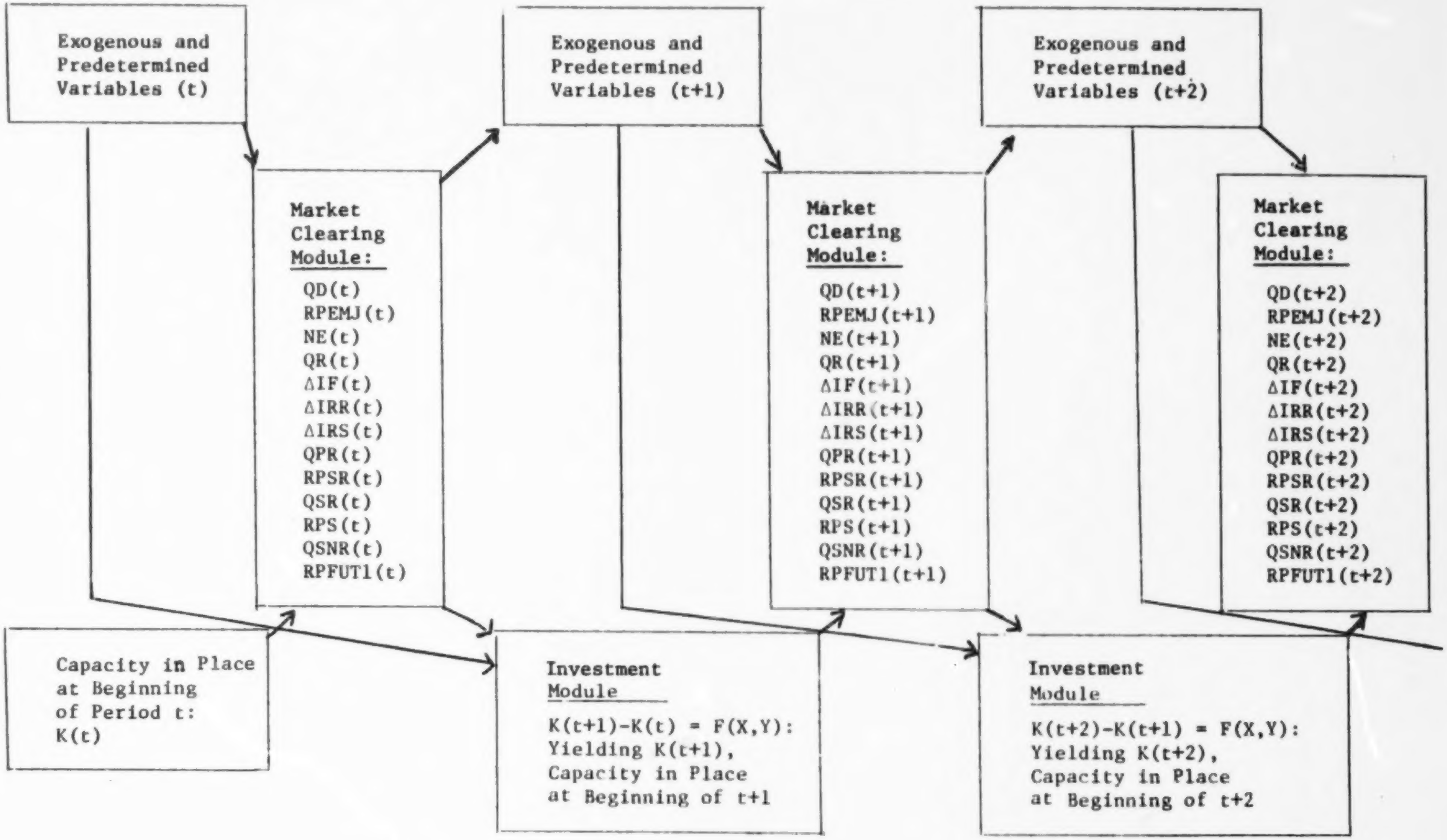
The Investment Module in Figure XI-4 is shown to utilize the Market Clearing Module solution to estimate the investment behavior of the primary producers. These results, together with other expectational and exogenous variables, are used to determine smelting/refining capacity expansion. Such capacity expansion, of course, affects capacity in place and, in turn, the cost curves of the primary copper producers.

Figure XI-5 summarizes the time sequencing of the interaction between the Market Clearing Module and the Investment Module. Given exogenous and predetermined variables and capacity in place at the beginning of year t, the Market Clearing Module of the model solves simultaneously for the thirteen (13) endogenous variables. Both the linear and nonlinear versions of the model are designed to yield, for any given year, three (3) parametric solution vectors for the endogenous variables corresponding to the three (3) parametric points which theoretically "bound" the primary producers' behavior and the solution space (discussed above). A solution vector for a single parametric point includes the output of the primary sector and the two secondary sectors, inventory changes, net exports, consumption of copper by the fabricators and semifabricators, and all prices in year t. Given the "most probable" (full cost pricing) parametric solution for year t, in addition to expectations on the part of the copper producers and the exogenous variables, the dynamic Investment Module solves for incremental capacity changes at the smelting and refining level during year t. These capacity changes are estimated and introduced into the cost curves of the primary producers for year t+1. The model then incorporates these changes in moving to year t+1 and simulating the market clearing solutions for that year.

Figure XI-5 further indicates how the model deals with the short-run and the long-run. The Market Clearing Module is essentially short-run, where the short-run is defined as a year. Capacity is fixed at the beginning of the year. There are no long-run cost, supply or demand curves involved in a given year's industry simulation. However, the sequence of short-run solutions are tied together by the Investment Module which treats capacity as variable and which charts the unfolding short-run over time. Thus, if one were to trace out the cost curves of the primary sector over time as capacity expands, the usual long-run envelope curves could be drawn for the marginal cost and average cost curves.

FIGURE XI-5

SIMPLIFIED DIAGRAM OF THE INTERACTION BETWEEN THE MARKET CLEARING MODULE AND THE INVESTMENT MODULE: A DYNAMIC VIEW


Exogenous and Predetermined Variables (t)
Market Clearing Module:
QD(t)
RPEMJ(t)
NE(t)
QR(t)
ΔIF(t)
ΔIRR(t)
ΔIRS(t)
QPR(t)
RPSR(t)
QSR(t)
RPS(t)
QSNR(t)
RPFUT1(t)
Capacity in Place at Beginning of Period t: K(t)
Exogenous and Predetermined Variables (t+1)
Market Clearing Module:
QD(t+1)
RPEMJ(t+1)
NE(t+1)
QR(t+1)
ΔIF(t+1)
ΔIRR(t+1)
ΔIRS(t+1)
QPR(t+1)
RPSR(t+1)
QSR(t+1)
RPS(t+1)
QSNR(t+1)
RPFUT1(t+1)
Investment Module
K(t+1)-K(t) = F(X,Y): Yielding K(t+1), Capacity in Place at Beginning of t+1
Exogenous and Predetermined Variables (t+2)
Market Clearing Module:
QD(t+2)
RPEMJ(t+2)
NE(t+2)
QR(t+2)
ΔIF(t+2)
ΔIRR(t+2)
ΔIRS(t+2)
QPR(t+2)
RPSR(t+2)
QSR(t+2)
RPS(t+2)
QSNR(t+2)
RPFUT1(t+2)
Investment Module
K(t+2)-K(t+1) = F(X,Y): Yielding K(t+2), Capacity in Place at Beginning of t+2

2. The Final Form of the Estimated Equations

Tables XI-1A - XI-1C contain the final form of the estimated equations for the linear and nonlinear versions of the model, for both the Market Clearing Module and the Investment Module, respectively. For a complete definition of the variables, refer to Appendix D.

Some of the more important conclusions emerging from the econometric work can be summarized as follows:

- The analysis of demand suggests that demand on the part of the fabricators and semifabricators is fairly price inelastic in both the short-run and the long-run. This inelasticity characterizes the own-price and cross-price (aluminum) elasticity estimates. A "remodified" flexible accelerator model proves quite useful in explaining inventory behavior. As would be expected, discretionary inventory behavior is most evident for the primary producers. The primary producers desire inventories for transactions purposes, in the face of strike expectations and for price-speculative reasons. However, their ability to achieve desired inventory positions is constrained by the use of the inventories to support the primary producers price (RPEMJ) in "demand-crunch" or "demand-slack" situations. The importance of alternative inventory motivations and the use of inventories to support pricing decisions is much less or non-existent for the fabricators/semifabricators and secondary refiners.

- The nonlinear and linear supply of nonrefined scrap is extremely inelastic. The nonlinear supply curve for secondary refining is elastic over 60-95 percent of capacity. At capacity, secondary refined supply becomes extremely inelastic. The linear version of secondary refined supply is also extremely inelastic.

- Smelting and refining capacity expansion on the part of the primary producers is related to their levels of mine output and their liquidity position as proxied by net income. Capactiy utilization and the cost of capital affect the capacity expansion significantly and with a time-lag.

TABLE XI-1A

FINAL FORM OF THE ESTIMATED EQUATIONS OF THE MARKET CLEARING MODULE, LINEAR VERSION

	Behavioral Relationships		R^2	$\hat{\rho}$	D.W.	F	Sample	Equation Number
1.	Demand	QD = 402.33 - 13.0839 RPEMJ + 45.4918 RPAL + 32.0311 YUD - 4.70229 IF(-1) + .270457 QD(-1) (.96) (-2.41) (3.54) (5.28) (-2.131) (1.23)	.92	-.286 (-1.23)	2.18	24.5	1954-1970	U1
2.	Inventory, Primary Producers	ΔIRR = .0917137 QPR + 2.60096 (RPFUT1 - RPEMJ) - 3.24347 (RPLME - RPEMJ) - 5.53020 DUMST2 - (.261623 + 1.0) IRR(-1) (7.81) (2.57) (-5.52) (-1.47) (-1.60)	.65	-.001	1.93		1951-1973	U4
3.	Inventory, Semi-Fabricators	ΔIF = .0274521 QFAB + 5.18061 DSTE2 - 6.14463 DUMST2 + (.571415 - 1.0) IF(-1) (2.48) (1.50) (-1.68) (3.19)	.37	.08	1.82		1953-1973	U3
4.	Inventory, Secondary Refiners	ΔIRS = .124286 QSR - .437843 (RPFUT1 - RPEMJ) + 1.45349 DUMST2 + (.381028 - 1.0) IRS(-1) (2.96) (-1.90) (.98) (2.00)	-.01	-.34	1.78		1953-1973	U5
5.	Net Exports	NE_t = 1745.3 + 3.7977 ($RPLME_t$ - $RPEMJ_t$) - 1179.3 $\frac{YUD_t}{YGR_t}$ - 32.3931 $DUMST2_t$ - 29.2512 TIME (5.7408) (1.96) (-4.8259) (-2.6634) (-4.8396)	0.80	.42	2.06		1954-1973	U2
6.	Secondary Supply, Refined	RPSR = 11.7669 + .0182204 QSR + .887223 RPS + 11.7036 (QR/KAPP) (.71) (.32) (4.85) (.66)	.85	.795 (6.28)	1.35	35.1	1950-1973	S2
7.	Secondary Supply, Scrap	RPS = -26.2524 + .0779355 QSNR (-1.56) (4.31)	.59	.48 (2.63)	1.80	30.14	1950-1973	S3
8.	Primary Supply, Parametric Solution Points	a) RPEMJ(t) = MC(t) = AVC(t) = VARCOS(t) b) RPEMJ(t) = $\lambda_0 + \lambda_1$ QPR(t) = ATC(t) c) MRPEMJ(t) = MC(t) = AVC(t) = VARCOS(t)						S1
9.	Price Equilibrium, Secondary Refined	RPSR - RPEMJ = -4.9518 + .381203 (RPLME - RPEMJ) + 10.7822 (QR/KAPP) (-.32) (3.53) (.54)	.67	.175 (.80)	1.91	16.97	1953-1973	ME 3
10.	Price Equilibrium Scrap	RPS - RPEMJ = -28.5832 + .255106 (RPLME - RPEMJ) + 18.3416 (QR/KAPP) (-2.13) (2.18) (1.07)	.59	.38 (2.05)	1.87	15.6	1948-1973	ME2
11.	Materials Balancing	QD + ΔIRR + ΔIF + ΔIRS + ΔIGOV + NE = QPR + QSR + QSNR						ME1
12.	Identity	QSR + QPR = QR						ID1
13.	Futures Price	RPFUT1 = 25.7988 + .454706 RPLME + 1.14595 DUMST2 (3.43) (4.29) (1.04)	.62	.24 (1.2)	1.73	16.5	1950-1973	ID2

NOTES: t statistics for H_0: parameter = 0 are given in parentheses.

TABLE XI-1B

FINAL FORM OF THE ESTIMATED EQUATIONS OF THE MARKET CLEARING MODULE, NONLINEAR VERSION

	Behavioral Relationships		R^2	$\hat{\rho}$	D.W.	F	Sample	Equation Number
1.	Demand	$QD = 402.33 - 13.0839\,RPEMJ + 45.4918\,RPAL + 32.0311\,YUD - 4.70229\,IF(-1) + .270457\,QD(-1)$ (.96) (-2.41) (3.54) (5.28) (-2.134) (1.23)	.92	-.286 (-1.23)	2.18	24.5	1954-1970	U1
2.	Inventory, Primary Producers	$\Delta IRR = .0917137\,QPR + 2.60096\,(RPFUT1 - RPEMJ) - 3.24347\,(RPLME - RPEMJ) - 5.5302\,DUMST2 - (.261623 + 1)\,IRR(-1)$ (7.81) (2.67) (-5.52) (-1.47) (-1.60)	.65	-.001	1.93		1951-1973	U4
3.	Inventory, Semi-Fabricators	$\Delta IF = .0274521\,QFAB + 5.18061\,DSTE2 - 6.14463\,DUMST2 + (.571415 - 1.0)\,IF(-1)$ (2.48) (1.50) (-1.68) (3.19)	.37	.08	1.82		1953-1973	U3
4.	Inventory, Secondary Refiners	$\Delta IRS = .124286\,QSR - .437843\,(RPFUT1 - RPEMJ) + 1.45349\,DUMST2 + (.381028 - 1.0)\,IRS(-1)$ (2.96) (-1.90) (.98) (2.00)	-.01	-.34	1.78		1953-1973	U5
5.	Net Exports	$NE_t = 1745.3 + 3.7977\,(RPLME_t - RPEMJ_t) - 1179.3\,\frac{YUD_t}{YGR_t} - 32.3931\,DUMST2_t - 29.2512\,TIME$ (5.7408) (1.96) (-4.8259) (-2.6634) (-4.8396)	0.80	.42	2.06		1954-1973	U2
6.	Secondary Supply, Refined	$RPSR = 44.489 - .32724\,QSR + .000772421\,QSR^2 + .714028\,RPS + 27.4509\,(QR/KAPP)$ (1.59) (-1.37) (1.41) (4.34) (1.81)	.88	.79 (6.39)	1.91	34.43	1951-1973	S2
7.	Secondary Supply, Scrap	$RPS = -26.2524 + .0779355\,QSNR$ (-1.56) (4.31)	.59	.48 (2.63)	1.80	30.14	1950-1973	S3
8.	Primary Supply, Parametric Solution Points	a) $RPEMJ(t) = AVC(t) = VARCOS(t) + \left(\frac{QPR(t) - .43\cdot KAPPR(t)}{.43\cdot KAPPR(t)}\right)^{31}$ b) $RPEMJ(t) = ATC(t) = VARCOS(t) + \frac{FIXCOS(t)}{QPR(t)} + \left(\frac{QPR(t) - .43\cdot KAPPR(t)}{.43\cdot KAPPR(t)}\right)^{35}$ c) $MRPEMJ(t) = MC(t) = VARCOS(t) + \left(\frac{QPR(t) - .43\cdot KAPPR(t)}{.43\cdot KAPPR(t)}\right)^{39}$						S1
9.	Price Equilibrium Secondary Refined	$RPSR - RPEMJ = -4.9518 + .381203\,(RPLME - RPEMJ) + 10.7822\,(QR/KAPP)$ (-.32) (3.53) (.54)	.67	.175 (.80)	1.91	16.97	1953-1973	ME3
10.	Price Equilibrium Scrap	$RPS - RPEMJ = -28.5832 + .255106\,(RPLME - RPEMJ) + 18.3416\,(QR/KAPP)$ (-2.13) (2.18) (1.07)	.59	.38 (2.05)	1.87	15.6	1948-1973	ME2
11.	Materials Balancing	$QD + \Delta IRR + \Delta IRS + \Delta IF + \Delta IGOV + NE = QPR + QSR + QSNR$						ME1
12.	Identity	$QSR + QPR = QR$						ID1
13.	Future Prices	$RPFUT\Delta = 25.7988 + .454706\,RPLME + 1.14595\,DUMST2$ (3.43) (4.29) (1.04)	.62	.24 (1.2)	1.73	16.5	1950-1973	ID2

NOTES: t statistics are given in parentheses for H_0: parameter = 0.

TABLE XI-1C

FINAL SPECIFICATIONS FOR THE INVESTMENT MODULE

Behavioral Relationships		R^2	$\hat{\rho}$	D.W.	F
1. Change in Smelting and Refining Capacity	$KAPPR_{t+1} - KAPPR_t = \underset{(3.46)}{.195771}\ QCUAV_t + \underset{(4.31)}{.00030014}\ NETAV_t + \underset{(4.23)}{196.295}\ (QR/KAPP)_{t-2} - \underset{(-4.31)}{133.022}\ CCAP11_{t-1} - \underset{(-5.75)}{.198956}\ KAPP_{t-1}$	.79	-.78 (-5.64)	2.66	36.5
2. Net Income	$NETY_t = \underset{(-3.25)}{-168812.0} + \underset{(2.81)}{2.69491}\ REVPR_t + \underset{(1.29)}{1.08624}\ REVPR_{t-1} + \underset{(2.09)}{2482.03}\ YUD_t$	.84	-.19 (-.86)	1.95	27.2
3. Supply of primary copper (implied by refined copper output)	$QCU_t = \underset{(.08)}{30.9529} + \underset{(1.98)}{.654612}\ QPR_t - \underset{(-1.50)}{.652478}\ QPR_{t-1} + \underset{(2.17)}{.708791}\ QPR_{t-2}$	.36	-.47 (-2.35)	1.81	2.94
4. Average Net Income	$NETYAV_t = .25\ (NETY_{t-1} + NETY_{t-2} + NETY_{t-3} + NETY_{t-4})$				
5. Average supply of primary copper	$QCUAV_t = .20\ (QCU_{t-1} + QCU_{t-2} + QCU_{t-3} + QCU_{t-4} + QCU_{t-5})$				

NOTES: t statistics in parentheses for H_o: parameter = 0.

In reviewing these results, a number of points should be noted:

- Significance of the estimated parameters:

  Of the total number of 44 estimated model parameters, 20 are significant at the 2 percent level, 4 at 2.5 percent, and 7 at 5 percent. Of the remainder, 7 are significant at the 10 percent level of significance, 5 at 20 percent, and one at 30 percent. Generally, no equation contains more than one "less significant" (or "insignificant") parameter; every coefficient that is crucial to the estimation of primary prices and production, which are the central focus of the model, are highly significant.

  It should be noted in this connection that the reported r-squares are, in at least three cases, quite low. These reported r-squares are not of the usual type. The computer software used to perform the two-stage estimates (more on this below) reports the multiple correlation coefficient associated with the instrumental variables rather than with the original variables. Consequently, the reported r-square is meaningless in the sense that it does not represent the proportion of the total variation explained by the estimated equation expressed in the original variables.

- Econometric criteria used:

  The r-square and the t statistics are only two of the criteria used for evaluating the statistical performance of econometric models. In our analysis, we hence did not concentrate on these statistics to the exclusion of all others. In order of importance, our concerns were that (1) each equation be theoretically plausible, (2) the sign of each coefficient be theoretically correct, (3) the effects on estimators of serial correlation be small, (4) the equations capture turning points, (5) the implied speeds of adjustment be consistent with available, but incomplete data. We then concentrated on the r-squares and t statistics. In order to satisfy these five stringent criteria, several alternative specifications of each equation were examined and extensive hypothesis testing was conducted. Although the final forms of the estimated equations do not, of course, satisfy all of these criteria perfectly, the Durbin-Watson statistics are good, all coefficients are of the correct sign and the adjustment speed appears to be reasonable.

- Historical model simulation and performance:

  The model was used to simulate the industry's growth and evolution over the period 1964-1973. The purpose of this exercise was not to simulate history with precision but to verify the reliability of the model in general terms and to assess the proximity and reasonableness of the model's three parametric solution results. Of course, to test the simulation powers of the model as a system, the industrial cost curves, a key determinant of the model solutions, would have to be adjusted to reflect the real factor prices and capacity obtaining in each year of the simulation period. This was not done. However, even without fine-tuning the cost curves, the nonlinear model appears to do a creditable job of simulating all but inventory behavior. Given the relatively small size of the inventory changes, the poor quality of the inventory data, and the minor role of inventory changes in explaining primary copper prices beyond the very short-run, it was decided that we could "make do" with these results. One additional conclusion of this admittedly crude simulation is that the effort devoted to developing the nonlinear version of the model appears to have been worthwhile. The linear model, the form most often employed in econometric work, is demonstratively inferior.

- The Use of Dummy Variables:

  The model includes a dummy variable for the occurrence and duration of strikes. It was found that the inclusion of such a strike variable improves some equations. Moreover, industry representatives have indicated that, because of the nature of the collective bargaining agreement, the timing and duration of strikes could be predicted with reasonable accuracy. Consequently, rather than ignoring it, we assumed that strikes would occur and that future strikes would be likely to follow historical patterns. We, however, consider this attempt to include strike activity within the forecast period to be a minor feature of the analysis.

3. Data Sources and Problems

Numerous data sources have been used in model construction, including published data from the Copper Development Association (CDA), American Bureau of Metal Statistics (ABMS), U.S. Bureau of Mines, Engineering and Mining Journal, results of a questionnaire survey of the industry, and the annual company reports, among others, (e.g., such as internal ADL data sources). The CDA time-series data on quantities (e.g., total copper consumption, output of primary refined copper, etc.) were used, with certain modifications, mostly because this procedure provided some semblance of accounting consistency.

The basic point to be made regarding data problems in the copper industry is that it would take considerable effort to develop a comprehensive set of internally consistent data accurately depicting this industry's activities. Existing data sources, are, to say the least, incomplete and inconsistent. Hence, substantial effort had to be devoted to making sure that the data used were largely internally consistent and of reliable accuracy. Estimates of productive capacity at the mining/milling and smelting/refining levels required far greater effort than originally anticipated.

4. Econometric Estimation Techniques Used

Both the linear and nonlinear versions of the model are linear in the parameters. Hence, linear estimation techniques were used. The data for the estimation usually covered the period 1947-1974.

The equations in the model contain endogenous variables and a lagged dependent variable on the right-hand side. The technique used in the model recognizes both these problems. The technique is that suggested by Fair and is essentially a combination of 2SLS and a correction for autocorrelation.[8] In general, the autocorrelation correction used was the iterative Cochrane-Orcutt technique.[9] There is the danger, however, that this technique may lead to a local rather than global minimum of the sum of squared residuals.[10] When this likelihood arose, the Hildreth-Lu scanning technique was used.[11] The Hildreth-Lu technique, given the use of a fairly refined grid, will give a global minimum.[12] Full information (3SLS) techniques or mixed 2SLS/3SLS techniques were not utilized, because the increased computational and analytical effort was judged unnecessary.

At several junctures in the course of the econometric analysis, the natural desire to fully analyze, formulate and test sharp behavioral hypotheses could not be completely fulfilled. The greatest analytical effort and consequently most thorough hypothesis testing has focused on demand for refined copper by fabricators and semifabricators, inventory behavior, the supply curves for the secondary producers, along with detailed engineering analysis of the cost functions for the primary producer. On the whole, the principal focus of the econometric analysis has been to develop sound behavioral specifications into a well-functioning simulation model. As a result, the econometric analysis was conducted until the behavioral specifications worked well in the model.

5. Mathematical Solution of the Model[13]

In spite of their functional, as well as pragmatic, desirability, the use of simultaneous nonlinear equations presented solution difficulties that were not easily overcome. Finally, a modified Newton-Raphson technique that is insensitive to the initial guess for the root was developed and used. It so happens that solution convergence using a Newton-Raphson technique is highly dependent upon the initial guess for the root. It was discovered fairly early that the use of the previous year's nonlinear parametric solutions and/or the use of the previous year's linear model solutions did not provide an "initial guess" good enough for convergence. In order to annually simulate an unfolding reality over a ten-to-twenty year period, it was hence necessary to develop a Newton-Raphson technique that is essentially independent of the initial guess for the root. In spite of this solution technique, the set of nonlinear equations were found to become ill-conditioned given some extreme values of the exogenous variables. For these reasons, the linear form of the model has been retained in order to back up the nonlinear model if "convergence" or "ill-conditioning" problems arise.

6. Basic Differences Between This and Other Econometric Models of the Copper Industry

Before designing, econometrically estimating and making operational the present model, an effort was made to review carefully not only past econometric studies of the copper industry but also the basic facts concerning the industry's organization, structure and operation. A critical review of the major recent econometric studies of the copper industry has been presented in the Technical Appendix. The modeling effort reported here differs from past econometric models of the copper industry in three respects.

First, an effort is made to develop a dynamic model of the industry, by explicitly embedding into the model the industry's smelting/refining investment behavior. Accordingly, smelting/refining capacity expansion is made endogenous in the present model. In this way, the model explicitly deals with the relationship between market clearing, which is essentially a short-run process and the creation of new capacity, which represents the adjustment process between the short-run and the long-run.

Second, going beyond the essentially static linear case, an attempt has been made here to develop a nonlinear model of the United States copper industry, which we feel introduces a far greater element of realism into the modeling effort.

Third, the industry supply curve utilized in past models for the primary producers is not supported by microeconomic theory under conditions where (as here) the behavior of the firms in the industry is not characterized by perfect competition. Hence, an explicit attempt has been made here to deal with the problem of a non-existent industry supply function by taking two direct approaches. First, attention is focused on the cost schedules of the primary producers, by estimating engineering cost functions and by building a link between capacity expansion and shifts in these cost functions. Secondly, the "parametric approach" is introduced to bound the model's solutions in any given year, as explained above.

Two additional points may be noted in this connection. First, the treatment of secondary copper in past studies, where all secondary copper is classified into old and new scrap, ignores the distinction between secondary refined copper and nonrefined scrap, which we have tried to retain in our analysis. Further, the categorization of ASARCO as a secondary refiner displays a basic confusion not only between custom-refining and toll-refining but also concerning ASARCO's role in the domestic copper industry. Quite apart from its role as a producer of secondary refined copper, ASARCO's activities have in the past included the smelting and refining of its own mine output, as well as custom and toll smelting/refining.

CHAPTER XI

NOTES

1. Oskar Morgenstern, "Thirteen Critical Points in Contemporary Economic Theory: An Interpretation". The Journal of Economic Literature, Vol. X, No. 4, (December 1972), p. 1163.

2. Oligopoly is probably the main market structure of the business world, a fact noted to the surprise of many in 1939 by Hall and Hitch as part of the studies of "The Oxford Economists Research Group." See R. L. Hall and C. J. Hitch, "Price Theory and Business Behavior," Oxford Economic Papers (1939); reprinted in T. Wilson and P. W. S. Andrews (eds.), Studies in the Price Mechanism (Oxford University Press, 1951).

3. For some discussion of this concept, see J. M. Clark, "Toward a Concept of Workable Competition," The American Economic Review, June 30, 1940, pp. 241-256 J. M. Clark, Competition as a Dynamic Process (Washington, D.C.: The Brookings Institution, 1961); C. E. Ferguson, A Microeconomic Theory of Workable Competition (Durham: Duke University Press, 1964); or F. M. Scherer, Industrial Market Structure and Economic Performance (Chicago: Rand McNally, 1971), pp. 33-38.

4. For a discussion and bibliography on "full cost pricing", see F. M. Scherer, Industrial Market Structure and Economic Performance (Chicago: Rand McNally, 1971) pp. 173-179, 223-224, 290, 305-306; and Edwin Mansfield, Microeconomic Theory and Applications (New York: W. W. Norton and Co., Inc., 1975)

5. For greater elucidation of the use of a target or desired rate of return see Lanzillotti, op. cit.; A. D. H. Kaplan, J. B. Dirlam and R. F. Lanzillotti, Pricing in Big Business (Washington, D.C.: The Brookings Institution, 1958), Scherer, op. cit., Chapters 6-9.

6. See Scherer, op. cit., Chapter 22; and Alfred Kahn, The Economics of Regulation, Vols. 1 and 2 (New York: John Wiley and Sons, 1970).

7. In a dynamic model, even this lower bound could be broken.

8. R. C. Fair, "The Estimation of Simultaneous Equation Models with Lagged Endogenous Variables and First Order Serially Correlated Errors," Econometrica, Vol. 38, May 1970, pp. 507-516.

NOTES
(Continued)

9. D. Cochrane and G. H. Orcutt, "Application of Least Square Regressions to Relationships Containing Autocorrelated Error Terms," Journal of the American Statistical Association, Vol. 44, 1949, pp. 32-61.

10. R. S. Pindyck and D. L. Rubinfeld, Econometric Models and Economic Forecasts, (New York: McGraw-Hill, 1976), pp. 111-112.

11. Hildreth and J. Y. Lu, "Demand Relations with Autocorrelated Disturbances," Michigan State University, Agricultural Experiment Station, Technical Bulletin 276, November, 1960.

12. R. S. Pindyck and D. L. Rubinfeld, op. cit., p. 112.

13. For a more detailed discussion, refer to Supporting Paper 6: "Mathematical Solution of the Model," given in the Technical Appendix.

XII. ECONOMIC IMPACT ANALYSIS

A. INTRODUCTION

This chapter presents an assessment of the economic impact of the presently promulgated air and water pollution abatement and control regulations on the United States copper industry over the period 1974-1987. As noted earlier, the objective of economic impact analysis is to identify and assess what effects, if any, environmental regulations would have on such key economic variables as prices, output, consumption, investment, employment and international trade, among others. It is also important to analyze the impact of compliance on the industry's structure, by considering effects on the degree of competitiveness or concentration, including effects on the international competitive position of the domestic industry. Finally, it is necessary to identify possible plant closures and assess regional or community impacts.

One main causal route through which environmental regulations may lead to such economic impacts is the additional cost borne by the industry to meet environmental regulations. The costs of compliance with environmental regulations, defined narrowly to include both capital expenditures (fixed costs) and operating and maintenance expenses (variable costs), cause an upward shift in the industry's pertinent cost schedules, thus ultimately affecting prices, production, and the whole range of economic variables indicated earlier. How precisely compliance costs affect production costs (or supply) becomes, therefore, analytically important for an economic impact analysis[1]. Compliance costs, serving generally as the central causal instrument, hence represent an input into economic impact analysis; compliance costs and economic impacts are, in this sense, not synonymous.

Another route through which environmental regulations may lead to such economic impacts is by adversely affecting, directly or indirectly, expansion in the industry's productive capacity. The promulgated environmental regulations may directly affect capacity growth by specifying in technical detail the conditions under which the industry may or may not expand existing capacity or build new capacity. Also, the effects on capacity growth may take a slightly indirect form, with potentially equal consequences: compliance costs may cause the actual shutdown of plants or may slow down capacity growth. Alternatively, the uncertainty caused by the evolving nature of environmental regulations plus costs of compliance may together impede capacity growth by influencing the timing of investment as well as perceptions concerning the riskiness of investment.

In the case of the domestic copper industry, the direct capacity-constraint or capacity-reducing influences of environmental regulations compound the economic impacts of compliance costs as such.

To recapitulate further, it is generally necessary to develop a model of the real world (i.e., the industry under consideration) which can be used for impact analysis. This is primarily because model building forces us to think clearly about and account for all the important interrelationships involved in a problem within a unified, internally consistent analytical framework. With or without models, the basic analytical issue at hand is to assess to what extent compliance with environmental regulations will influence the course of a set of pertinent economic variables (at the national, industry and regional levels), over a period of time in the future. Therefore, economic impacts are typically measured as differences from a set of baseline forecasts. Baseline forecasts trace out the values that all pertinent variables would take, over a period of time, in the absence of environmental regulations (or at least in substantial absence of environmental regulations). With the regulations, both because of increased costs of production due to compliance costs and the direct and indirect adverse effects on capacity growth, the same variables would take new values, over the same time period. The differences are attributed to the environmental regulations.

We have assessed the economic impacts of the presently promulgated air and water regulations on the United States copper industry by developing and using an econometric model of the United States copper industry. A general description of this model has been presented in Chapter XI. A detailed description of the model is given in a separate volume prepared as a technical appendix to this report[2].

The model is currently programmed to simulate the growth and evolution of the industry year-by-year through 1987. The model is used to develop annual forecasts over the period 1974-1987, which defines the impact analysis period, under baseline conditions as well as under alternative environmental scenarios. Under baseline conditions, the model internally (endogenously) forecasts the industry's smelting/refining capital expenditures for both replacement and expansion and therefore the industry's smelter/refinery capacity growth. Under environmental scenarios, smelter/refinery capacity growth is no longer internally forecasted by the model for reasons detailed in Chapter X and summarized below. For impact analysis it was necessary to conduct a smelter-by-smelter analysis outside the model, develop alternative compliance and capacity growth scenarios, build the results into the model and subsequently use the model to determine the economic impacts of both compliance costs and direct effects on capacity growth simultaneously. What the model does for impact analysis purposes, therefore, is simply to spell out in comprehensive quantitative terms the implications of both compliance costs and direct effects on capacity growth.

In the rest of this chapter, our aim is to present and interpret main economic impacts of alternative environmental scenarios. To this end, we start with a definition of the baseline conditions and forecasts which provide a point of reference for impact analysis. Following this, we defined several environmental scenarios (e.g., "constrained capacity", "reduced capacity") for economic impact and sensitivity analysis. These environmental scenarios basically represent alternative pictures as to the industry's ability to change domestic smelter capacity during the impact analysis period under the presently promulgated environmental regulations. A discussion of the economic impact results under these environmental scenarios, using the model, is presented next. We then discuss the sensitivity of the impact results to alternative sets of assumptions on capacity growth and compliance costs.

The impact results derived (quantitatively) from the model have broader implications or raise other issues that we have attempted to identify next. These broad issues/implications, some of which would be of obvious policy concern, are identified by reference to three major areas: (a) the present regulatory environment, (b) issues pertaining to the growth of the domestic copper industry, and (c) international economic implications.

Appendix D contains model printouts giving baseline forecasts and the results of the key scenarios tested.

B. BASELINE CONDITIONS AND FORECASTS

Baseline conditions, or forecasts, help define the growth, evolution and performance of the United States copper industry, over the impact analysis period, in the absence (or substantial absence) of the presently promulgated environmental regulations and, hence, provide a point of reference from which comparisons can be made in order to gauge the relative and absolute magnitude of economic impacts.

Before presenting the baseline forecasts, a number of points relating to the definition, interpretation, and analytical use of baseline conditions deserve emphasis. These points refer to (1) how baseline conditions help measure impacts, (2) what they include or exclude in terms of environmental regulations, (3) how the impact analysis period is defined, and (4) exactly how the baseline conditions are defined in terms of the assumptions made on macroeconomic growth and related factors.

1. Use of Baseline Conditions in Impact Analysis

We should note immediately that many baseline forecasts are possible for the future, each representing a particular combination of an expected set of circumstances. For this reason, a given set of baseline forecasts should be viewed not as the only or even as the most likely future state of the world but rather as a fairly reasonable approximation of a generally plausible future picture of the world which can be used as a benchmark for comparison, keeping in mind that many other and perhaps equally plausible future states of the world may be possible.

Further, it is important to bear in mind that when economic impacts are measured as differences from a given set of baseline forecasts, expressing these differences in absolute terms could magnify the impacts if, for example, higher baseline conditions are hypothesized (e.g., higher macroeconomic growth, etc.). Conversely, the opposite effect, too, could potentially result. In short, to minimize potential misuses of the baseline concept in impact analysis, emphasis is generally put not on absolute differences from baseline conditions but on relative (percentage) differences.

Keeping these two basic points in mind, the model was run under numerous baseline scenarios before it was used for impact analysis, to safeguard against any systematic bias in the measurement of impacts. To this end, we have specifically examined the following:

- alternative macroeconomic recovery and growth scenarios ("slow", "moderate", "robust"), including expected economic recovery and growth in Europe;
- alternative sets of forecasts of LME refined copper prices, consistent with the forecasted macroeconomic conditions (both in the United States and Europe) and reflecting expected growth in mined copper output in the rest of the world;
- alternative estimates of unit costs of production, as well as a close analysis of increases in costs of production at production levels near full capacity (e.g., in the region beyond roughly 86 percent of installed capacity);
- alternative mining/milling investment levels, estimates of the cost of capital, target rates of return, machinery/equipment retirement rates, capital charge coefficients on existing and new (both productive and pollution control) investment; and,
- alternative estimates of future aluminum production costs and prices, particularly in view of the threat of the cartelization of bauxite and the energy content of aluminum production.

We have generally found the model's results to be directionally correct, consistent with theory, and extremely stable, under a broad range of assumptions/conditions. The impacts measured in relative terms are found to be generally similar under alternative combinations of baseline conditions, incorporating "high", "low", and "standard" macroeconomic growth scenarios.

2. Environmental Regulations Included under Baseline Conditions and Related Issues

The baseline forecasts assume the existence of National Ambient Air Quality Standards (NAAQS) but the absence of additional restrictions regarding how such standards might be achieved. This means, in other words, nominal industry compliance with NAAQS, through minimal permanent control and extensive use of SCS, but no constraints on the modes of capacity growth. As a related matter, the baseline costs for new capacity assume that this capacity would be built with acid plants for controlling strong streams, but without other pollution control measures. Pollution control costs are hence treated as part of the cost of production.

3. Definition of the Impact Analysis Period

Definition of the impact analysis period also specifies the period over which baseline conditions need to be hypothesized. Typically, the impact analysis period pertains to the future, not to the past. However, in this case, the impact of environmental regulations in past years could not be entirely ignored. Hence, the impact analysis period was defined as the 1974-1987 time span, where 1974, the base year in our analysis, is also the start of the impact analysis period. The year 1987 represents the terminal year of the second Nonferrous Smelter Order (NSO) period as specified under the Clean Air Act Amendments of 1977.

This provides both a practical and a theoretical compromise; while it correctly emphasizes future impacts, it does not altogether ignore impacts created in the past. At the same time, it recognizes the near intractability of ascertaining clearly the impacts created in the past, especially before 1974, given the presence of many intervening factors which are not at all easy to disentangle. For example, industry representatives have indicated that the unprecedented price increases and the consequent shortage mentality in 1974 might not have occurred (or would have occurred to a much smaller degree) if the industry's investment resources were not diverted during and prior to this period into unproductive pollution abatement investment. Unfortunately, such propositions are not amenable to unambiguous analysis or proof. Consequently, that part of the baseline model simulation which specifically covers the 1974-1977 period is only an attempt at determining the course of evolution the industry would have followed over these years, in the substantial absence of environmental regulations but given the macroeconomic and related conditions which have, in fact, prevailed.

At any rate, the 1974-1987 period allows for a sufficiently long time horizon, as far as the future is concerned (i.e., 1978-1987) for spelling out in reasonable detail the short, intermediate and long-term implications of the presently promulgated environmental regulations. Such a definition also adequately accounts for the industry's long-run adjustment process, in terms of productive capacity expansion, in view of the fact that it would probably take as long as seven years for a minimum efficient size smelter to be brought on-stream.

4. Assumptions on Macroeconomic Growth and Related Factors

The macroeconomic growth scenario that is assumed generally reflects moderate and steady growth in overall economic activity in the United States. The European economies, meanwhile, are expected to follow a slightly slower recovery and growth path, lagging the United States.

Appendix D contains a tabulation of the numerical values assumed for all the exogenous variables in the model in defining the baseline conditions, including the assumed macroeconomic growth rates (i.e., growth in the industrial production index for manufactured durable goods), the LME copper prices, future aluminum prices, industry average variable costs, industry mine/mill investment, and others. The assumptions made on these exogenous variables are generally congruent with each other (e.g., all else being equal, low LME prices would be consistent with slow economic recovery in Europe).

5. Baseline Forecasts

Baseline forecasts for the United States copper industry reflecting the above considerations are tabulated in Table XII-1, for such selected variables as total copper consumption, net imports, production of primary refined copper, secondary refined copper supply (transacted on the "outside" market), total production of scrap copper that is directly consumed, prices of domestic primary refined copper, secondary refined copper prices (translated on the "outside" market), and prices of scrap copper. Also tabulated are employment, total effective domestic smelter/refinery capacity and capacity utilization rates.

TABLE XII-1

TABULATION OF BASELINE FORECASTS FOR THE UNITED STATES COPPER INDUSTRY FOR SELECTED VARIABLES, 1974-1987

(Selected Years)

(All dollar figures in 1974 prices; quantities are in thousands of short tons.)

Description of variables	1974	1977	1979	1981	1983	1985	1987
Total copper consumption[c]	3,397.8	3,455.1	3,792.4	4,027.3	4,221.8	4,567.9	4,864.3
Net imports[b]	167.1	239.6	274.3	361.5	356.0	513.8	571.2
Primary refined copper production[a]	1,792.7	2,060.7	2,191.6	2,314.7	2,477.5	2,688.4	2,897.3
Production of refined copper from scrap[d]	285.2	236.3	243.0	243.9	250.0	248.5	252.1
Total quantity of scrap generated (which is directly consumed)	1,229.5	874.2	1,078.0	1,118.3	1,153.9	1,136.2	1,159.0
Primary refined copper prices (¢/lb.)	77.2	56.4	68.9	72.9	76.6	74.8	77.2
Prices of secondary refined copper (¢/lb.)	88.5	58.2	75.6	78.2	80.5	79.3	80.8
Prices of scrap (¢/lb. of refined copper equivalent)	69.6	41.9	57.8	60.9	63.7	62.3	64.1
Primary smelter capacity (thousands of short tons of copper production per year)	1,992.0	2,380.5	2,506.0	2,615.2	2,808.1	3,056.2	3,300.0
Capacity utilization (%)	90.0	86.6	87.5	88.5	88.2	88.0	87.6
Total employment[e]	45,902	51,410	54,551	57,428	61,302	63,338	71,094

NOTES:

[a] Domestic production of refined copper by primary producers, from all sources (domestically mined copper, imported ore/concentrate/blister/scrap, domestically generated unalloyed scrap): although it contains some secondary refined copper, it is exclusive of secondary refined output produced by secondary refiners.

[b] Net of exports.

[c] Includes primary and secondary refined copper, directly consumed scrap and imports.

[d] Refined copper from scrap sold on the "outside" market.

[e] Total full-time equivalent employment (number of persons) including mining and milling, smelting and refining employment at all domestic primary producer facilities; employment by secondary smelters/refiners is excluded.

SOURCES: COPMOD I (i.e., the acronym used for the Econometric Simulation and Impact Analysis Model of the U.S. Copper Industry developed as part of this project; refer to Chapter XI for a general description and to the Technical Appendix accompanying this volume for a detailed description of this model).

C. ALTERNATIVE ENVIRONMENTAL AND INDUSTRY CAPACITY GROWTH SCENARIOS FOR ECONOMIC IMPACT ANALYSIS

This section discusses, in less technical terms than in Chapter X, the impact of the presently promulgated air and water pollution control regulations on domestic primary smelter capacity growth over the next decade, with the purpose of defining alternative capacity growth scenarios for economic impact analysis.

1. Domestic Primary Smelter Capacity Growth in the Past: A Recapitulization

Chapter VI contained a detailed description of the pattern of domestic primary smelter capacity expansion in the past. The basic conclusion emerging from this discussion was that the domestic copper industry has traditionally preferred incremental expansion at existing sites, rather than the construction of new (greenfield) smelters. The lead time required for planning, engineering, construction, shake-down and start-up for small expansions at existing sites is about two-to-three years while that for new (greenfield) smelters is about seven years, given the current state of the industry.

2. Impact of Regulations on Domestic Primary Smelter Capacity Growth in the Future: Main Conclusions

Chapter X presented a detailed discussion of the impact of the Clean Air Act (including the Clean Air Act Amendments of 1977) on modes of capacity growth in the industry. Two major conclusions pertaining to smelter capacity expansion were drawn from this discussion. First, existing regulations do not allow for small expansions of the type used traditionally by the industry. Second, while there are some uncertainties, the regulations appear to allow the construction of NSPS caliber (or better) smelters in new locations and also in existing smelter locations. However, because of the lead time requirements, major new capacity of this type is not likely to come on-stream before 1985. Furthermore, the reverb-based smelters will have to undergo major alterations to non-reverb technology by 1988 or shut down.

These major findings indicate that the currently promulgated environmental regulations will effectively constrain domestic capacity growth until 1985. In the interim, minor increases in capacity are expected for hydrometallurgical processing of oxides and expansion at non-reverb smelters.

3. Plausible Patterns of Domestic Primary Smelter Capacity Growth in the Future: An Exploration of Alternatives

Between now and January 1, 1988, various possibilities exist for the expansion (or contraction) of the smelting capacity in the copper industry. These possibilities are listed below. It should be noted that every available capacity expansion path is not equally plausible.

The various paths are:

- All existing smelters will be in compliance by January 1, 1988;
- One or more of the existing smelters will be closed down sometime during this period, while all others will be in compliance by 1988;
- One or more new (greenfield) smelters will come on-stream during the period 1985-1987;
- Additional electrowinning capacity will be brought on-stream over this period (i.e., 1978-1987); and,
- Four nonreverberatory furnace smelters (Inspiration, Anaconda, Hidalgo, and Garfield) will be permitted to increase their combined effective capacity by about 120,000 annual short tons of refined copper equivalent production as long as they use NSPS caliber technology.

Two additional channels relating to copper supply have been omitted from this list: secondary copper (i.e., refined scrap or scrap that is directly consumed) and imports. Both of these supply channels are treated endogenously in the model; the secondary sectors enter the model as two supply equations and imports are handled through a "net exports" (or "net imports") equation.

4. Definition of Basic Capacity Growth Scenarios for Economic Impact Analysis

As noted in Chapter X, there are many alternative routes through which domestic primary smelter capacity might effectively change over the next decade. From these we have selected two capacity change routes as the most plausible for the purpose of economic impact analysis. They are labeled "Constrained Capacity" and "Reduced Capacity". These two basic scenarios are defined as follows:

a. Constrained Capacity

This scenario assumes that none of the existing smelters will shut down; all smelters currently employing reverberatory furnaces will make progress towards compliance by January 1, 1988 and that the bulk of the smelter conversion costs would be incurred during the second NSO period (i.e., 1984-1987); and that no new (greenfield) smelter capacity will be coming on-stream during this period, and only marginal electrowinning capacity is expected to be introduced over the five-year period 1983-1987 (20,000 annual short tons of refined copper equivalent per year; 100,000 annual short tons cumulatively over the five year period).

b. Reduced Capacity

This scenario, which is the more severe, assumes that three smelters (i.e., Phelps Dodge-Douglas, Kennecott-McGill, and Asarco-Tacoma or an equivalent smelter) will close down in 1983, for various reasons noted in Chapter X. These three smelters have a combined capacity of 268,000 annual short tons of refined copper equivalent production (i.e., Douglas 90,000; McGill 78,000; and Tacoma 100,000 annual short tons). As under the Constrained Capacity scenario, no new (greenfield) smelter capacity will be coming on-stream during this period, and only marginal electrowinning capacity is expected to be introduced during the five-year period 1983-1987 (same as under Constrained Capacity).

c. Capacity Growth Scenarios for Sensitivity Analysis

As noted below, a series of sensitivity tests were performed by modifying the Constrained Capacity and Reduced Capacity scenarios. The various sensitivity test scenarios are defined in detail below. These sensitivity tests incorporated the following principal modes of capacity growth:

- NSPS Expansion: This assumes that the four non-reverb smelters will be permitted to expand by 1982 by a cumulative total of 120,000 annual short tons of refined copper equivalent.
- New Smelters: This assumes two new (greenfield) smelters will come on-stream, the first in 1985 and the second in 1987, each with a capacity of 200,000 annual short tons of refined copper equivalent.
- Effect of SCS: This assumes a 10 percent reduction in existing reverb-based capacity because of the use of SCS.

D. DISCUSSION OF ECONOMIC IMPACTS UNDER "CONSTRAINED CAPACITY" AND "REDUCED CAPACITY" SCENARIOS

The model has been used to measure economic impacts under the Constrained Capacity and Reduced Capacity scenarios, as defined above. Model results under the two capacity scenarios, together with assumptions on exogenous variables, are presented in Appendix D, which also contains the baseline forecasts.

Estimated pollution abatement and control capital expenditures, as well as operating and maintenance costs, over the period 1974-1987 under the environmental scenarios just described, are given in Table XII-2. Capital expenditures for pollution abatement and control undertaken in a given year do not necessarily measure actual costs incurred in

TABLE XII-2

ESTIMATES OF POLLUTION ABATEMENT AND CONTROL EXPENDITURES BY THE UNITED STATES COPPER INDUSTRY[a], 1974-1987

(In millions of 1974 dollars)

Year	CONSTRAINED CAPACITY					REDUCED CAPACITY				
	Capital Expenditures[b]			Operating and Maintenance Costs[e]	TOTAL	Capital Expenditures[b]			Operating and Maintenance Costs	TOTAL
	Non-reverberatory Related Capital Expenditures	Reverberatory Conversion Investment[c]	Total			Non-reverberatory Related Capital Expenditures	Reverberatory Conversion Investment[d]	Total		
1974	226.0	-	226.0	57.4	283.4	226.0	-	226.0	57.4	283.4
1975	240.8	-	240.8	49.3	290.1	240.8	-	240.8	49.3	290.1
1976	156.0	-	156.0	48.8	204.8	156.0	-	156.0	48.8	204.8
1977	90.0	-	90.0	42.3	132.3	90.0	-	90.0	42.3	132.3
1978	60.0	-	60.0	98.0	158.0	60.0	-	60.0	98.0	158.0
1979	40.0	-	40.0	88.2	128.2	40.0	-	40.0	88.2	128.2
1980	40.0	-	40.0	89.5	129.5	40.0	-	40.0	89.5	129.5
1981	40.0	-	40.0	89.8	129.8	40.0	-	40.0	89.8	129.8
1982	40.0	-	40.0	89.6	129.6	40.0	-	40.0	89.9	129.9
1983	40.0	156.5	196.5	90.0	286.5	40.0	126.7	166.7	78.6	245.3
1984	40.0	156.5	196.5	89.8	286.3	40.0	126.7	166.7	78.4	245.1
1985	40.0	156.5	196.6	90.1	286.6	40.0	126.7	166.7	78.5	245.2
1986	40.0	156.5	196.5	90.2	286.7	40.0	126.7	166.7	78.5	245.2
1987	-	156.5	196.5	90.0	246.5	-	126.7	126.7	78.4	205.1
1974-1987	1,092.8	782.5	1,875.3	1,103.0	2,978.3	1,092.8	633.5	1,726.3	1,045.6	2,771.9
1978-1987	380.0	782.5	1,162.5	905.2	2,067.7	380.0	633.5	1,013.5	847.8	1,861.3

NOTES:

[a] Not including secondary smelters/refiners.

[b] Figures given here refer to expenditures (dollar outflows), not to increased fixed costs. In the model, these investment figures are translated into annualized fixed costs through the use of capital charge coefficients (refer to Arthur D. Little, Inc., Econometric Simulation and Impact Analysis Model of the U.S. Copper Industry, Technical Appendix to this report.

[c] Estimated by using the following formula:

$$I_t^{rc} = u \cdot \left(\frac{K_o^s - K_o^{nr} - K_o^e}{T}\right)$$

where

I_t^{rc} : reverberatory conversion investment in year t (t = 1983, ..., 1987), in millions of 1974 dollars:

u : reverberatory conversion investment per unit of capacity (assumed at about $600 per annual short ton of refined copper equivalent production; this cost assumption, which represents only a rough first approximation, requires a more detailed case-by-case examination);

K_o^s : total United States smelter capacity at the beginning of 1978 (i.e., year "o"), defined in terms of annual short tons of refined copper equivalent production (annual short tons) including electrowinning capacity (estimated at 2,326 annual short tons);

K_o^{nr} : nonreverberatory smelter capacity at the beginning of 1978 (estimated at 746,000 annual short tons), consisting of the following:

Phelps Dodge-Hidalgo	(100,000 annual short tons)
Kennecott-Garfield	(280,000 annual short tons)
Anaconda-Anaconda	(216,000 annual short tons)
Inspiration-Inspiration	(150,000 annual short tons);

K_o^e : total estimated other smelter-equivalent capacity (basically electrowinning) at the beginning of 1978 (estimated at 276,000 annual short tons);

T : period of years during which conversion investment would be assumed to take place (assumed to be five years; the 1983-1987 period is assumed as the most likely period for such investment to take place; it is further assumed that such investment will be spread equally over each year during this period).

[d] Same as Note "c", except that the reverberatory conversion investment given here exclude three smelters with reverberatory furnaces which are assumed to be closed down in 1983 (these are: Phelps-Dodge, 90,000 annual short tons; Kennecott-McGill, 78,000 annual short tons; and Asarco-Tacoma, 100,000 annual short tons, or an equivalent smelter) see the accompanying text for more detail.

[e] Increases in annual variable costs due to pollution abatement and control, estimated at about 1.8 cents per pound over the period 1974-1977 and 2.5 cents per pound therefater. The estimates given here are obtained by multiplying the refined copper equivalent smelter production levels (adjusted for electrowinning capacity) by 1.8¢/lb. for years 1974-1977 and by 2.5¢/lb. for years 1978-1987. The production data used for years 1974-1977 refer to actual domestic refined copper production levels (from domestic and foreign ores), as published by the United States Bureau of Mines; the data for years 1978-1987 are the model forecasts of domestic refined copper production levels by primary producers (under the two basic environmental impact scenarios).

SOURCE: Arthur D. Little, Inc.

TABLE XII-3

TRANSLATION OF ESTIMATED POLLUTION ABATEMENT AND CONTROL CAPITAL EXPENDITURES BY THE UNITED STATES COPPER INDUSTRY INTO ANNUALIZED FIXED COSTS, 1970-1987

(in millions of 1974 dollars)

"CONSTRAINED CAPACITY" SCENARIO

(Pollution Abatement and Control Expenditures, by Year in which such expenditures are incurred)

Years When Fixed Costs Are Faced	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	Annualized Fixed Costs By Year[a]
	20.9	30.0	146.4	204.6	226.0	240.8	156.0	90.0	60.0	40.0	40.0	40.0	40.0	196.5	196.5	196.5	196.5	156.5	
1970	3.55																		3.55
1971	3.55	5.10																	8.65
1972	3.55	5.10	24.89																33.54
1973	3.55	5.10	24.89	34.78															68.32
1974	3.55	5.10	24.89	34.78	38.42														106.74
1975	3.55	5.10	24.89	34.78	38.42	40.94													147.68
1976	3.55	5.10	24.89	34.78	38.42	40.94	26.52												174.20
1977	3.55	5.10	24.89	34.78	38.42	40.94	26.52	15.30											189.50
1978	3.55	5.10	24.89	34.78	38.42	40.94	26.52	15.30	10.20										199.70
1979	3.55	5.10	24.89	34.78	38.42	40.94	26.52	15.30	10.20	6.80									206.50
1980	3.55	5.10	24.89	34 78	38.42	40.94	26.52	15.30	10.20	6.80	6.80								213.30
1981	3.55	5.10	24.89	34.78	38.42	40.94	26.52	15.30	10.20	6.80	6.80	6.80							220.10
1982	3.55	5.10	24.89	34.78	38.42	40.94	26.52	15.30	10.20	6.80	6.80	6.80	6.80						226.90
1983	0.63	5.10	24.89	34.78	38.42	40.94	26.52	15.30	10.20	6.80	6.80	6.80	6.80	33.41					257.39
1984	0.63	0.90	24.89	34.78	38.42	40.94	26.52	15.30	10.20	6.80	6.80	6.80	6.80	33.41	33.41				286.60
1985	0.63	0.90	4.39	34.78	38.42	40.94	26.52	15.30	10.20	6.80	6.80	6.80	6.80	33.41	33.41	33.41			299.51
1986	0.63	0.90	4.39	6.14	38.42	40.94	26.52	15.30	10.20	6.80	6.80	6.80	6.80	33.41	33.41	33.41	33.41		304.28
1987	0.63	0.90	4.39	6.14	6.78	40.94	26.52	15.30	10.20	6.80	6.80	6.80	6.80	33.41	33.41	33.41	33.41	26.61	299.25

NOTES: [a]These estimates, obtained outside the model (where annualization is computed internally), reflect the following major assumptions: (1) capital recovery period of 13 years, (2) fixed charge coefficient of 0.17 (i.e., 17 percent), (3) continued fixed cost at 3 percent of original cost beyond the first 13 years, to reflect continued general administrative expenses and replacement investment. It is implicit in these assumptions that the full initial cost is paid off in 13 years.

SOURCE: Arthur D. Little, Inc., estimates.

TABLE XII-4

TRANSLATION OF ESTIMATED POLLUTION ABATEMENT AND CONTROL CAPITAL EXPENDITURES BY THE UNITED STATES COPPER INDUSTRY INTO ANNUALIZED FIXED COSTS, 1970-1987

(in millions of 1974 dollars)

"REDUCED CAPACITY" SCENARIO

(Pollution Abatement and Control Capital Expenditures, by Year in which such expenditures are incurred)

Years When Fixed Costs Are Faced	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	Annualized Fixed Costs By Year[a]
	20.9	30.0	146.4	204.6	226.0	240.0	156.0	90.0	60.0	40.0	40.0	40.0	40.0	166.7	166.7	166.7	166.7	126.7	
1970	3.55																		3.55
1971	3.55	5.10																	8.65
1972	3.55	5.10	24.89																33.54
1973	3.55	5.10	24.89	34.78															68.32
1974	3.55	5.10	24.89	34.78	38.42														106.74
1975	3.55	5.10	24.89	34.78	38.42	40.94													147.68
1976	3.55	5.10	24.89	34.78	38.42	40.94	26.52												174.20
1977	3.55	5.10	24.89	34.78	38.42	40.94	26.52	15.30											189.50
1978	3.55	5.10	24.89	34.78	38.42	40.94	26.52	15.30	10.20										199.70
1979	3.55	5.10	24.89	34.78	38.42	40.94	26.52	15.30	10.20	6.80									206.50
1980	3.55	5.10	24.89	34.78	38.42	40.94	26.52	15.30	10.20	6.80	6.80								213.30
1981	3.55	5.10	24.89	34.78	38.42	40.94	26.52	15.30	10.20	6.80	6.80	6.80							220.10
1982	3.55	5.10	24.89	34.78	38.42	40.94	26.52	15.30	10.20	6.80	6.80	6.80	6.80						226.90
1983	0.63	5.10	24.89	34.78	38.42	40.94	26.52	15.30	10.20	6.80	6.80	6.80	6.80	28.34					252.32
1984	0.63	0.90	24.89	34.78	38.42	40.94	26.52	15.30	10.20	6.80	6.80	6.80	6.80	28.34	28.34				276.46
1985	0.63	0.90	4.39	34.78	38.42	40.94	26.52	15.30	10.20	6.80	6.80	6.80	6.80	28.34	28.34	28.34			284.30
1986	0.63	0.90	4.39	6.14	38.42	40.94	26.52	15.30	10.20	6.80	6.80	6.80	6.80	28.34	28.34	28.34	28.34		284.00
1987	0.63	0.90	4.39	6.14	6.78	40.94	26.52	15.30	10.20	6.80	6.80	6.80	6.80	24.34	28.34	28.34	28.34	21.54	273.90

NOTES: [a] These estimates, obtained outside the model (where annualization is computed internally), reflect the following major assumptions: (1) capital recovery period of 13 years, (2) fixed charge coefficient of 0.17 (i.e., 17 percent), (3) continued fixed cost at 3 percent of original cost beyond the first 13 years, to reflect continued general administrative expenses and replacement investment. It is implicit in these assumptions that the full initial cost is paid off in 13 years.

SOURCE: Arthur D. Little, Inc., estimates.

that or subsequent years. This is because the use of a machine or equipment extends many years over which its initial cost is amortized. Hence, the real cost of machinery or equipment is spread over a period, typically defined as the capital recovery period in investment analysis, and encompasses depreciation, interest payments and the like. These are fixed costs, faced annually, over many years. It is therefore necessary to translate initial pollution abatement and control investment levels into fixed costs spread over many years, using capital charge coefficients. This is accomplished in Tables XII-3 and XII-4.

Tables XII-5 and XII-6 summarize the estimated annualized fixed costs and variable (operating and maintenance) costs over the period 1974-1987 (in constant 1974 dollars) due to pollution abatement and control under the two environmental scenarios.

The combined effects of both capacity constraints and pollution control expenditures in terms of their economic impacts are summarized below.

1. Summary of Economic Impacts

Table XII-7 compares the baseline with the Constrained Capacity and Reduced Capacity Scenario results. The impacts can be summarized as follows:

a. Impact on Prices

Compared to the baseline, real prices in 1981 are 10.4 percent higher under both Constrained Capacity and Reduced Capacity scenarios. In 1983, real prices are 15.8 percent higher under Constrained Capacity and 26.1 percent under Reduced Capacity, the difference between the two reflecting the assumed closing down of three smelters in that year. During the period immediately after 1983, price impacts show a sharp deterioration. Under Constrained Capacity, for example, prices are 23.3 percent higher in 1985 and 29.4 percent higher in 1987 than those prevailing under baseline conditions. These reflect the combined effects of both compliance costs and the limitation on capacity growth. The price impacts become even higher under Reduced Capacity: real prices are 32.8 percent above that expected to prevail under baseline conditions in 1985 and 38.7 percent in 1987.

TABLE XII-5

ANNUALIZED FIXED AND VARIABLE (OPERATING AND MAINTENANCE) COSTS DUE TO POLLUTION ABATEMENT AND CONTROL, THE UNITED STATES COPPER INDUSTRY, 1974-1987

(in millions of 1974 dollars)

"CONSTRAINED CAPACITY" SCENARIO

Years	Annualized Fixed Costs[a]	Variable (Operating and Maintenance) Costs	Total Annualized Costs[a]
1974	106.7	57.4	164.1
1975	147.7	49.3	197.0
1976	174.2	48.8	223.0
1977	189.5	42.3	231.8
1978	199.7	98.0	297.7
1979	206.5	88.2	294.7
1980	213.3	89.5	302.8
1981	220.1	89.8	309.9
1982	226.9	89.6	316.5
1983	257.4	90.0	347.4
1984	286.6	89.8	376.4
1985	299.5	90.1	389.6
1986	304.3	90.2	394.5
1987	299.3	90.0	389.3

NOTES: [a] It should be noted that annualized fixed costs over the period 1974-1987 include annualized fixed costs due to pollution abatement and control capital expenditures incurred in earlier years.

SOURCE: Based on Tables XII-2 and XII-3.

TABLE XII-6

ANNUALIZED FIXED AND VARIABLE (OPERATING AND MAINTENANCE) COSTS DUE TO POLLUTION ABATEMENT AND CONTROL, THE UNITED STATES COPPER INDUSTRY, 1974-1987

(in millions of 1974 dollars)

"REDUCED CAPACITY" SCENARIO

Years	Annualized Fixed Costs[a]	Variable (Operating and Maintenance) Costs	Total Annualized Costs[a]
1974	106.7	57.4	161.4
1975	147.7	49.3	197.0
1976	174.2	48.8	223.0
1977	189.5	42.3	231.8
1978	199.7	98.0	297.7
1979	206.5	88.2	294.7
1980	213.3	89.5	302.8
1981	220.1	89.8	309.9
1982	226.9	89.9	316.8
1983	252.3	78.6	330.9
1984	276.5	78.4	354.9
1985	284.3	78.5	362.8
1986	284.0	78.5	362.5
1987	273.9	78.4	352.3

NOTES: [a] It should be noted that annualized fixed costs over the period 1974-1987 include annualized fixed costs due to pollution abatement and control capital expenditures incurred in earlier years.

SOURCE: Based on Tables XII-2 and XII-4.

TABLE XII-7

ECONOMIC IMPACTS UNDER ALTFRNATIVE ENVIRONMENTAL SCENARIOS AND CORRESPONDING COMPLIANCE COSTS ON THE UNITED STATES COPPER INDUSTRY 1974-1987: SUMMARY OF SELECTED RESULTS

(all dollar figures in 1974 prices; quantities are in thousands of short tons)

IMPACT VARIABLE/SCENARIO	1974	1977	1979	1981	1983	1985	1987
Primary Refined Copper Prices							
Baseline	77.2	56.4	68.9	72.9	76.6	74.8	77.2
Constrained Capacity	77.3	59.4	73.5	80.5	88.7	92.2	99.9
Reduced Capacity	77.3	59.4	73.5	80.5	96.6	99.3	107.1
% Differences from Baseline							
Constrained Capacity	0.1	5.3	6.7	10.4	15.8	23.3	29.4
Reduced Capacity	0.1	5.3	6.7	10.4	26.1	32.8	38.7
Primary Refined Copper Production[a]							
Baseline	1792.7	2060.7	2191.6	2314.7	2477.5	2688.4	2897.3
Constrained Capacity	1790.6	1971.2	2039.6	2072.4	2095.6	2136.6	2175.5
Reduced Capacity	1790.6	1971.2	2039.6	2072.4	1867.3	1905.5	1943.0
% Difference from Baseline							
Constrained Capacity	-0.1	-4.3	-6.9	-10.5	-15.4	-20.5	-24.9
Reduced Capacity	-0.1	-4.3	-6.9	-10.5	-24.6	-29.1	-32.9
Net Imports[b]							
Baseline	167.1	239.6	274.3	361.5	356.0	513.8	571.2
Constrained Capacity	167.4	251.5	292.5	391.8	404.0	583.0	661.1
Reduced Capacity	167.4	251.5	292.5	391.8	435.2	611.2	689.6
% Differences from Baseline							
Constrained Capacity	0.2	4.9	6.6	8.4	13.5	13.5	15.7
Reduced Capacity	0.2	4.9	6.6	8.4	22.2	18.9	20.7
Total Consumption[c]							
Baseline	3397.8	3455.1	3792.4	4027.3	4221.8	4567.9	4864.3
Constrained Capacity	3396.9	3405.9	3708.6	3899.7	4019.3	4274.1	4474.1
Reduced Capacity	3396.9	3405.9	3708.6	3899.7	3917.0	4147.2	4345.2
% Differences from Baseline							
Constrained Capacity	-0.02	-1.4	-2.2	-3.2	-4.8	-6.4	-8.0
Reduced Capacity	-0.02	-1.4	-2.2	-3.2	-7.2	-9.2	-10.7
Employment[d]							
Baseline	62,953	58,051	64,886	68,530	73,350	79,595	85,780
Constrained Capacity	62,879	55,530	60,386	61,357	62,044	63,258	64,410
Reduced Capacity	62,879	55,530	60,386	61,357	55,285	56,416	57,526
% Differences from Baseline							
Constrained Capacity	-0.1	-4.3	-6.9	-10.5	-15.4	-20.5	-24.9
Reduced Capacity	-0.1	-4.3	-6.9	-10.5	-24.6	-29.1	-32.9

NOTES: [a] Domestic production of refined copper by primary producers, from all sources (domestically mined copper, imported ore/concentrate/blister/scrap, domestically generated unalloyed scrap); although it contains some secondary refined copper, it is exclusive of secondary refined output produced by secondary refiners.

[b] Net of exports.

[c] Includes primary and secondary refined copper, directly consumed scrap and imports.

[d] Total full-time equivalent employment (number of persons) including mining and milling, smelting and refining employment at all domestic primary producers facilities; employment by secondary smelters/refiners are excluded.

SOURCE: COPMOD I (i.e., the acronym used for the Econometric Simulation and Impact Analysis Model of the U.S. Copper Industry developed as part of this project; refer to Chapter XI for a general description and to the Technical Appendix accompanying this volume for a detailed description of this model).

The forecasts of prices under the Constrained Capacity and Reduced Capacity scenarios should be interpreted as the price levels that would be expected to result from environmental regulations in the absence of a massive infusion of imports into the United States. Imports would be much higher if the rest-of-the-world (LME) copper prices stay lower than those assumed under baseline conditions. The baseline conditions already show a persistent increase in the level of imports; a reversal of past trends.

b. Impacts on Production

The impact on domestic primary refined copper production closely parallels the impact on copper prices, but in the opposite direction. Namely, by 1981, domestic refined copper output falls 10.5 percent below the baseline output level under both scenarios. By 1983, domestic production is 15.4 percent below the baseline level under Constrained Capacity and 24.6 percent under Reduced Capacity. The full force of the negative impact is felt in 1987, when domestic production falls 24.9 percent below the baseline forecast under Constrained Capacity and 32.9 percent under Reduced Capacity.

c. Impact on International Trade

The overall pattern emerging from the model forecasts under baseline conditions is that net imports show a persistent increase over time, which represent a reversal of past trends. Under both Constrained Capacity and Reduced Capacity, net imports become 8.4 percent higher in 1981 than the level expected under baseline conditions. Under Constrained Capacity, net imports in the 1980s are generally 13-15 percent above baseline levels. The reduction in domestic capacity in 1983 leads to net imports rising 22.2 percent above the baseline level in that year; by 1987, under Reduced Capacity, net imports still remain 20.7 percent above the baseline level.

While these international trade impacts, especially under Reduced Capacity, should be considered important enough for policy concern, they nevertheless might appear less serious than would have been expected. One explanation is that, with capacity expansion constrained in the United States, world prices would tend to rise, which in turn would result in a drop in demand for copper from external sources. Another answer, more applicable to Reduced Capacity, could be that the speed of adjustment to lower prices in the rest of the world on the part of the domestic consumers, is perhaps not as fast or automatic as would have been thought. This is consistent with the behavior of the independent fabricators in the past when they continued to purchase copper from the primary producers even when copper at lower prices was available on the "outside" market.

d. Impact on Consumption

Consistent with economic theory, total consumption (which include primary and secondary refined copper, scrap directly consumed and imports) falls from baseline levels, under both the Constrained Capacity and Reduced Capacity scenarios, due to substantially higher prices. The fall in consumption reaches 8.0 percent in 1987 under Constrained Capacity and 10.7 percent under Reduced Capacity. The drop in total consumption is not as serious as in domestic refined copper production, since demand for copper remains relatively inelastic and consumers make greater use of secondary refined copper, scrap, and imports, while restraining their consumption somewhat because of higher prices.

e. Impact on Employment

Under both the Constrained Capacity and the Reduced Capacity scenarios, industry-wide employment at all stages of production--mining through refining--is expected to be felt sharply in terms of curtailing employment growth that would otherwise be expected to occur under baseline conditions. Basically, Constrained Capacity would prevent about 21,000 full-time equivalent jobs and Reduced Capacity nearly 28,000 jobs by 1987, which respectively represents 24.9 percent and 32.9 percent less employment than under baseline conditions[3]. It should be noted that no significant compensating employment growth in the secondary copper industry is expected. Likewise, employment growth at smelters due to pollution abatement would be relatively small.

These employment impacts do not reflect layoffs but represent lower potential growth in a few Western states where domestic copper mining, milling and smelting operations are largely concentrated[4]. As noted in Chapter III, principal copper producing states in 1974 were Arizona (56 percent of total United States mine production of recoverable copper), Utah (14 percent), New Mexico (12 percent), Montana (8 percent), Nevada (5 percent), and Michigan (4 percent).

The distribution of copper mining and milling employment by state in 1974 was as follows:

(SIC 1021--Copper Ores Mining and Milling)

State	Employment (June 1974)[a]	Percent Breakdown (%)
Arizona	27,372	59.2
Utah	5,899	12.8
New Mexico	2,764	6.0
Montana	4,008	8.7
Nevada	2,094	4.5
Michigan	2,790	6.0
Other[b]	1,279	2.8
TOTAL	46,206	100.0

NOTES: [a] Number of persons employed (both supervisory and non-supervisory or production workers) figures refer to June, 1974--a peak month in 1974.

[b] Includes the following: Missouri (502), New York (381), and Texas (123).

SOURCE: United States Bureau of Labor Statistics, Employment and Wages, Second Quarter 1974, Table C-8 (p. 70).

Further, of the total smelting and refining employment of 17.2 thousand in 1972, more than half of 9.0 thousand was concentrated in the five-state Mountain region (Montana, New Mexico, Arizona, Utah and Nevada). Arizona alone accounted for 3.0 thousand (17.4 percent). The Northeast Region, basically covering operations in New York (Phelps Dodge-Laurel Hill), New Jersey (Asarco-Perth Amboy, which has since closed down), Maryland (Kennecott-Anne Arundel County; Asarco-Baltimore, which has since closed down), Pennsylvania (Reading Industries, Inc.-Reading), accounted for 6.6 thousand (or 25.6 percent)[5].

f. Community Impacts

If Kennecott-McGill (Nevada) and Phelps Dodge-Douglas (Arizona) smelters actually do close down, as hypothesized under the Reduced Capacity Scenario, the impact on these two isolated communities, which are essentially one-industry towns, would be severe. If, similarly, Asarco-Tacoma is closed down, as further hypothesized under the Reduced Capacity Scenario, the local impact would be quite significant.

These three smelters together employ about 3,100 persons (McGill, 1,480; Douglas, 610; Tacoma, 1,000). The McGill smelter accounts for over half the jobs in White Pine County, which contains McGill. Similarly, the Douglas smelter is a major employer, providing about 15 percent of total jobs in that community. Finally, the Tacoma smelter has remained, over many decades, a significant source of employment in Tacoma, even though the smelter currently contributes just over one percent of all jobs in Greater Tacoma (Pierce County).

2. Related Findings

a. Impact on Capacity Growth and Utilization of Capacity

As shown in Table XII-8 the shortfall in domestic primary smelting/refining capacity compared to the baseline reaches 874 thousand annual short tons of refined output under Constrained Capacity and 1,142 thousand annual short tons under Reduced Capacity by 1987.

Capacity utilization is, as expected, high throughout the period. While both the capacity shortfall and the utilization rates projected may be less serious under slower economic growth scenarios, the situation could be more critical than projected here under a higher growth macroeconomic scenario.

The capacity utilization rates shown in Table XII-8 appear consistent both directionally and in terms of the numerical magnitudes involved, when the baseline, Constrained Capacity and Reduced Capacity results are cross-compared. The utilization rates become higher as we move away from baseline conditions towards Constrained Capacity and they become even higher under Reduced Capacity. These results are as expected both in theory and in practice.

The following related points, in this connection, should be noted[6]: (i) the "optimal" capacity utilization rate for the industry, in terms of producing at minimum average total cost is roughly around 86 percent of installed capacity; (ii) beyond this region, the average total cost of production rises rapidly and very steeply near the "practical" capacity limit (at roughly 92 percent of installed capacity, due to irreducible shutdown for repairs, etc.); (iii) consequently, prolonged production along this segment of the industry's average total cost, average variable cost, or marginal cost schedules would occur at higher costs and therefore at higher prices as long as there is no sharp fall in demand (such as in 1975); (iv) therefore, capacity constraints imposed under Constrained Capacity and Reduced Capacity would inevitably lead to higher prices, in a strictly microeconomic sense, all else remaining equal (e.g., barring a sudden opening up of the domestic market to a massive infusion of foreign imports). These effects are quantified, in an internally consistent way, by the model.

b. Impact on Secondary Copper Prices and Production

Impact results for secondary copper prices and production are tabulated in Table XII-9. The basic conclusion emerging from the model is that prices of both secondary refined copper sold on the "outside" market and scrap prices rise rapidly in response to domestic primary smelting/refinery capacity constraints. In response to these price increases, production of secondary refined copper (produced by secondary smelters/refiners) rises only very slowly, given the fairly inelastic supply function econometrically estimated for secondary smelters/refiners. The situation is different, however, with respect to the supply of scrap that goes directly into the consumption stream: production rises more sharply in response to rising prices.

TABLE XII-8

DOMESTIC PRIMARY SMELTING/REFINING CAPACITY GROWTH AND CAPACITY UTILIZATION UNDER ALTERNATIVE SCENARIOS, 1974-1987

(capacity in thousands of annual short tons of refined copper equivalent production)

	1974	1977	1979	1981	1983	1985	1987
Baseline							
Capacity	1992.0	2380.5	2506.0	2615.2	2808.1	3056.2	3299.9
Percent Capacity Utilization	90.0	86.6	87.5	88.5	88.2	88.0	87.8
Constrained Capacity							
Capacity	1992.0	2272.0	2326.0	2326.0	2346.0	2386.0	2426.0
Percent Capacity Utilization	89.9	86.8	87.7	89.1	89.3	89.5	89.7
Reduced Capacity							
Capacity	1992.0	2272.0	2326.0	2326.0	2078.0	2118.0	2158.0
Percent Capacity Utilization	89.9	86.8	87.7	89.1	89.9	90.0	90.0

SOURCE: COPMOD I.

TABLE XII-9

SUMMARY OF IMPACTS ON SECONDARY COPPER PRICES AND PRODUCTION, 1974-1987

(all dollar figures in 1974 prices; quantities are in thousands of short tons)

	1974	1977	1979	1981	1983	1985	1987
Prices of Secondary Refined Copper[a]							
Baseline	88.5	58.2	75.6	78.2	80.5	79.3	80.8
Constrained Capacity	88.5	60.1	78.5	82.9	88.1	90.3	95.1
Reduced Capacity	88.5	60.1	78.5	82.9	93.1	94.8	99.6
Production of Refined Copper from Scrap[b]							
Baseline	285.2	236.3	243.0	243.9	249.9	248.5	252.1
Constrained Capacity	285.5	236.3	248.6	251.9	260.1	262.9	269.5
Reduced Capacity	285.5	236.3	248.6	251.9	266.2	268.4	274.6
Prices of Scrap							
Baseline	69.6	41.9	57.8	60.9	63.7	62.3	64.1
Constrained Capacity	69.6	44.1	61.3	66.7	72.9	75.6	81.4
Reduced Capacity	69.6	44.1	61.3	66.7	78.9	81.0	86.8
Quantity of Scrap Generated[c]							
Baseline	1229.5	874.2	1077.9	1118.3	1153.9	1136.2	1159.0
Constrained Capacity	1229.9	903.3	1122.8	1193.1	1272.7	1307.1	1380.9
Reduced Capacity	1229.9	903.3	1122.8	1193.1	1349.5	1376.4	1450.9

NOTES: [a] Secondary refined copper produced by secondary smelters/refiners and sold on the "outside" market.

[b] Refers to production by secondary smelters/refiners only.

[c] Excludes scrap going into the smelting/refining stream.

SOURCE: COPMOD I.

It should be noted that both prices and production of secondary refined copper and scrap are directionally correct under the various scenarios.

It should finally be noted that price differences from the baseline become quite serious in the 1980s. By 1987, secondary refined prices are 17.7 percent higher than the baseline under Constrained Capacity and 23.3 percent higher under Reduced Capacity. Scrap prices display a similar pattern; by 1987, they are 27.0 percent higher under Constrained Capacity and 35.4 percent higher under Reduced Capacity.

3. Sensitivity Analysis

We have conducted a sensitivity analysis to see how the impact results reported above might change under a somewhat different specification of the environmental/industry capacity growth scenarios. Specifically, focusing on the Constrained Capacity and the Reduced Capacity scenarios, we have defined and tested the implications of the following new scenarios:

- Constrained Capacity I (Sensitivity 1): which assumes that the Constrained Capacity scenario outlined above is relaxed by allowing for new grassroots smelter/refinery capacity to come on-stream in 1985 (200,000 ast--annual short tons of refined copper equivalent production--) and again in 1987 (200,000 ast). These two additions of new smelter/refinery capacity will cost an estimated $680 million, spread over many years; of this total, an estimated $160 million will represent investment for pollution control, spread over the years 1982-1986. It is further assumed that these new additions to smelter/refinery capacity will be accompanied by parallel new mine and mill investment of equal productive capacity, estimated at about $1,360 million spread over the years 1982-1986. These developments will be in addition to the compliance cost and capacity growth assumptions already incorporated into the Constrained Capacity scenario.

- Reduced Capacity I (Sensitivity 2): which represents a modification of the Reduced Capacity scenario by introducing exactly the same new capacity growth and compliance cost assumptions as just described under Constrained Capacity I (Sensitivity 1).

- Reduced Capacity II (Sensitivity 3): which represents a modification of the Reduced Capacity scenario by introducing two new assumptions. The first is that the effective domestic reverb-based smelter capacity will be further curtailed over the period 1983-1987 by 10 percent due to SCS. Secondly, compliance cost investment over the period 1979-1986 will be $80 million/year (compared with $40 million/year assumed initially under the Reduced Capacity scenario); also, pollution control-related increase in average variable costs is assumed to be 1.8¢/lb. over the period 1974-1978, 2.5¢/lb. in 1979 and 4¢/lb. over the period 1980-1987 (compared with 1.8¢/lb. over the period 1974-1977 and 2.5¢/lb. over the period 1978-1987 assumed initially under Reduced Capacity).

- Reduced Capacity III (Sensitivity 4): which represents a modification of the Reduced Capacity scenario by incorporating the assumption that the effective domestic smelting capacity will increase by 60,000 ast in 1981 and by another 60,000 ast in 1982 by increasing the smelting rate (NSPS expansion, as explained in Chapter X), requiring an investment of about $24 million, of which roughly $16 million will be for pollution control. It is further assumed that this increase in effective smelter capacity will be accompanied by parallel mine and mill investment of equal productive capacity, estimated at about $408 million spread over the years 1979-1981.

- Reduced Capacity IV (Sensitivity 5): which represents a modification of the Reduced Capacity scenario by assuming higher LME copper prices during the 1982-1987 period (80¢/lb. over the period 1982-1984 and 85¢/lb. over the period 1985-1987, in real 1974 terms), reflecting possible upward worldwide price adjustments during this period caused in part by the hypothesized reduction in domestic productive smelter capacity (e.g., in the form of an international commodity agreement, etc.).

The results of the sensitivity analysis are reported in Tables XII-10A through XII-10E where the results for selected key impact variables are summarized. An examination of these results generally indicates that the severity of the adverse impacts reported earlier, would remain broadly unchanged. As might be expected, the impacts are less severe when new capacity is allowed to come on-stream during the period 1985-1987. Everything considered, the lowest deviations from baseline appear to be those associated with the Constrained Capacity I scenario, which allows for new smelters to come on-stream in 1985 and in 1987.

E. BROADER IMPLICATIONS OF ENVIRONMENTAL REGULATIONS AND RELATED ISSUES

The environmental regulations and the impact results discussed earlier have broader implications and raise certain issues which deserve emphasis. These pertain to the regulatory environment, growth of the domestic copper industry and international economic implications.

1. Regulatory Environment

Environmental regulations not only lead to increased production costs due to the cost of compliance, but also and perhaps more importantly, cause uncertainty because of their evolving nature.

TABLE XII-10A

ECONOMIC IMPACTS UNDER ALTERNATIVE ENVIRONMENTAL SCENARIOS AND CORRESPONDING COMPLIANCE COSTS ON THE UNITED STATES COPPER INDUSTRY 1974-1987

SUMMARY OF SENSITIVITY ANALYSIS RESULTS ON PRIMARY REFINED COPPER PRODUCTION[a]

(in thousands of short tons)

Description	1974	1977	1979	1981	1983	1985	1987
Environmental Scenarios							
Baseline	1,792.7	2,060.7	2,191.6	2,314.7	2,477.5	2,688.4	2,897.3
Constrained Capacity I	1,790.6	1,971.2	2,039.6	2,072.4	2,086.6	2,273.2	2,463.9
Reduced Capacity I	1,790.6	1,971.2	2,039.6	2,076.2	1,877.6	2,060.0	2,100.2
Reduced Capacity II	1,790.6	1,971.2	2,026.2	2,069.2	1,773.6	1,811.1	1,848.0
Reduced Capacity III	1,790.6	1,971.2	2,036.6	2,115.3	1,968.3	2,008.0	2,046.5
Reduced Capacity IV	1,790.6	1,971.2	2,039.6	2,072.4	1,867.2	1,904.5	1,942.5
Percent Difference from Baseline (%)							
Constrained Capacity I	0	-4.3	-6.9	-10.5	-15.8	-15.4	-15.0
Reduced Capacity I	0	-4.3	-6.9	-10.3	-24.2	-23.4	-27.5
Reduced Capacity II	0	-4.3	-7.5	-10.6	-28.4	-32.6	-36.2
Reduced Capacity III	0	-4.3	-7.1	-8.6	-20.6	-25.3	-29.4
Reduced Capacity IV	0	-4.3	-6.9	-10.5	-24.6	-29.2	-33.0

NOTES: [a] Domestic production of refined copper by primary producers, from all sources (domestically mined copper, imported ore/concentrate/blister/scrap, domestically generated unalloyed scrap); although it contains some secondary refined copper, it is exclusive of secondary refined output produced by secondary refiners.

SOURCE: COPMOD I.

TABLE XII-10B

ECONOMIC IMPACTS UNDER ALTERNATIVE ENVIRONMENTAL SCENARIOS AND CORRESPONDING COMPLIANCE COSTS ON THE UNITED STATE COPPER INDUSTRY 1974-1987
SUMMARY OF SENSITIVITY ANALYSIS RESULTS ON PRIMARY REFINED COPPER PRICES

(cents per pound)

Description	1974	1977	1979	1981	1983	1985	1987
Environmental Scenarios							
Baseline	77.2	56.4	68.9	72.9	76.6	74.8	77.2
Constrained Capacity I	77.3	59.4	73.5	80.5	89.0	87.4	90.4
Reduced Capacity I	77.3	59.4	73.5	80.4	95.9	94.1	102.2
Reduced Capacity II	77.3	59.4	73.9	80.6	99.6	102.3	110.0
Reduced Capacity III	77.3	59.4	73.6	79.0	93.3	96.2	103.9
Reduced Capacity IV	77.3	59.4	73.5	80.5	96.5	98.6	106.7
Percent Differences From Baseline (%)							
Constrained Capacity	0	5.3	6.7	10.4	16.2	16.8	17.1
Reduced Capacity I	0	5.3	6.7	10.2	25.2	25.8	25.0
Reduced Capacity II	0	5.3	7.3	10.6	30.0	36.8	42.5
Reduced Capacity III	0	5.3	6.8	8.4	21.8	28.6	34.6
Reduced Capacity IV	0	5.3	6.7	10.4	26.0	31.8	38.3

SOURCE: COPMOD I.

TABLE XII-10C

ECONOMIC IMPACTS UNDER ALTERNATIVE ENVIRONMENTAL SCENARIOS AND CORRESPONDING COMPLIANCE COSTS ON THE UNITED STATES COPPER INDUSTRY 1974-1987

SUMMARY OF SENSITIVITY ANALYSIS RESULTS ON COPPER CONSUMPTION[a]

(in thousands of short tons)

Description	1974	1977	1979	1981	1983	1985	1987
Environmental Scenarios							
Baseline	3,397.8	3,455.1	3,792.4	4,027.3	4,221.8	4,567.9	4,864.3
Constrained Capacity I	3,396.9	3,405.9	3,708.6	3,899.7	4,015.0	4,333.7	4,617.8
Reduced Capacity I	3,396.9	3,405.9	3,708.6	3,901.3	3,900.4	4,216.5	4,432.0
Reduced Capacity II	3,396.9	3,405.9	3,703.1	3,897.8	3,863.6	4,094.8	4,292.5
Reduced Capacity III	3,396.9	3,405.9	3,707.4	3,918.6	3,971.8	4,203.8	4,402.6
Reduced Capacity IV	3,396.9	3,405.9	3,708.6	3,899.7	3,919.9	4,158.3	4,351.6
Percent Difference From Baseline (%)							
Constrained Capacity	0	-1.4	-2.2	-3.2	-4.9	-5.1	-5.1
Reduced Capacity I	0	-1.4	-2.2	-3.1	-7.6	-7.7	-8.9
Reduced Capacity II	0	-1.4	-2.4	-3.2	-8.5	-10.4	-11.8
Reduced Capacity III	0	-1.4	-2.2	-2.7	-6.9	-8.0	-9.5
Reduced Capacity IV	0	-1.4	-2.2	-3.2	-7.2	-9.0	-10.5

NOTES: [a] Includes primary and secondary refined copper, directly consumed scrap and imports.

SOURCE: COPMOD I.

TABLE XII-10D

ECONOMIC IMPACTS UNDER ALTERNATIVE ENVIRONMENTAL SCENARIOS AND CORRESPONDING COMPLIANCE COSTS ON THE UNITED STATES COPPER INDUSTRY 1974-1987 SUMMARY OF SENSITIVITY ANALYSIS RESULTS ON NET IMPORTS[a]

(in thousands of short tons)

Description	1974	1977	1979	1981	1983	1985	1987
Environmental Scenarios							
Baseline	167.1	239.6	274.3	361.5	356.0	513.8	571.2
Constrained Capacity I	167.4	251.6	292.5	391.8	405.1	563.9	623.5
Reduced Capacity I	167.4	251.6	292.5	391.4	432.3	590.3	670.3
Reduced Capacity II	167.4	251.6	294.2	392.1	447.2	622.8	701.3
Reduced Capacity III	167.4	251.6	292.9	385.9	422.3	598.6	676.9
Reduced Capacity IV	167.4	251.6	292.5	391.8	415.2	568.5	648.5
Percent Difference From Baseline (%)							
Constrained Capacity I	0	5.0	6.6	8.4	13.8	9.8	9.2
Reduced Capacity I	0	5.0	6.6	8.3	21.4	14.9	17.4
Reduced Capacity II	0	5.0	7.2	8.5	25.6	21.2	22.8
Reduced Capacity III	0	5.0	6.7	6.8	18.6	16.5	18.5
Reduced Capacity IV	0	5.0	6.6	8.4	16.6	10.6	13.5

NOTES: [a]Net of exports.

SOURCE: COPMOD I.

TABLE XII-10E

ECONOMIC IMPACTS UNDER ALTERNATIVE ENVIRONMENTAL SCENARIOS AND CORRESPONDING COMPLIANCE COSTS ON THE UNITED STATES COPPER INDUSTRY 1974-1987

SUMMARY OF SENSITIVITY ANALYSIS RESULTS ON EMPLOYMENT[a]

Description	1974	1977	1979	1981	1983	1985	1987
Environmental Scenarios							
Baseline	62,953	58,051	64,886	68,530	73,350	79,595	85,780
Constrained Capacity I	62,440	55,530	60,386	61,357	61,778	67,302	72,948
Reduced Capactiy I	62,440	55,530	60,386	61,470	55,590	60,990	62,180
Reduced Capacity II	62,440	55,530	59,989	61,627	52,511	53,621	64,713
Reduced Capacity III	62,440	55,530	60,297	62,627	58,275	59,450	60,590
Reduced Capacity IV	62,440	55,530	60,386	61,357	55,282	56,386	57,511
Percent Difference From Baseline (%)							
Constrained Capacity I	0	-4.3	-6.9	-10.5	-15.8	-15.4	-15.0
Reduced Capacity I	0	-4.3	-6.9	-10.3	-24.2	-23.4	-27.5
Reduced Capacity II	0	-4.3	-7.5	-10.6	-28.4	-32.6	-36.2
Reduced Capacity III	0	-4.3	-7.1	-8.6	-20.6	-25.3	-29.4
Reduced Capacity IV	0	-4.3	-6.9	-10.5	-24.6	-29.2	-33.0

NOTES: [a] Total full-time equivalent employment (number of persons) including mining and milling, smelting and refining employment at all domestic primary producer facilities; employment by secondary smelters/refiners are excluded.

SOURCE: COPMOD I.

For the copper industry, a major source of uncertainty in the future relates to the fugitives problem (i.e., the magnitude of the fugitive emissions, the degree to which they might contribute to the violation of ambient standards even in the vicinity of smelters using modern, "exemplary" technology and the means which might be used to alleviate this problem).

From a planning standpoint, the problem of uncertainty is bound to increase the degree of risk associated with a new project and increase the required ex ante rate of return on investment. The increased degree of perceived risk may further make the industry more cautious and increase both the lead times and the costs required for adding new capacity. Because of both such cost increases and compliance costs faced by the industry, the realized rate of return may also be negatively impacted, especially during macroeconomic downswings ("demand slack" periods) when the domestic producers would be particularly constrained in their ability to "pass on" cost increases owing to increased competition presented by foreign producers during such periods. These factors, combined with the cumulative and sometimes conflicting nature of the regulations, may further be creating a broader set of unintended consequences, for example, by effectively curtailing expansion of domestic productive capacity in a more general sense. Moreover, the existence of many regulatory agencies affecting a given industry, with little or no coordination among them (in the apparent absence of any legal requirement for them to coordinate their activities), may well compound the unintended and unforeseen effects of their actions falling upon the industry being regulated.

In this report, we have assumed that this fugitives problem will be resolved in a fashion such that it does not affect existing capacity or impede the construction of new capacity. Consistent with this and the other regulations explicitly covered in this report, the "Constrained Capacity" scenario appears to be the most likely.

The Reduced Capacity scenario assumes that EPA will require all smelters to embark on a definitive program for meeting the 1988 requirements for attaining ambient standards through the use of permanent controls alone. This scenario becomes less likely if Congress changes the requirements of the Act or if the EPA allows the smelters to stay open until 1988.

The expansion of NSPS smelters will be more likely if these four smelters have attained their ultimate emissions limit. If not, these smelters would be in nonattainment and could expand only if there was an emissions offset. Since most smelters are the sole SO_2 emitting source in their respective air quality regions, such an emissions offset would not be achieved with NSPS caliber technology.

Other uncertainties exist which would indicate that the actual impact on the industry might possibly fall outside the range "bounded" by the Constrained Capacity and Reduced Capacity scenarios:

- From a statutory viewpoint, the states can require standards that are "tougher" than Federal standards. This and the requirement for case-by-case review can contribute to the "moving target" nature of the regulations. It should be noted that regional EPA offices often provide technical help to the state environmental agencies and can be involved in providing technical guidance on such matters.

- Several proposed OSHA regulations will affect productivity in the copper industry. In some instances, EPA and OSHA requirements are in conflict (e.g., OSHA will permit control of ambient concentrations via dilution while EPA will not). For example, if gases from a multiple-hearth roaster are to be used in an acid plant to reduce SO_2 emissions, such roasters would have to operate at a low draft to reduce dilution of this gas. OSHA requirements might require operation of such roasters under higher draft. In general, while OSHA requires the use of engineering controls to reduce ambient concentrations, such controls achieve little to meet EPA requirements. In other words, except for fugitives, there is little synergism between EPA and OSHA control costs and such costs are additive. OSHA regulations which would affect the copper industry are those for inorganic arsenic, lead, SO_2 etc.

The new NSO process introduced by the 1977 Clean Air Act Amendments (explained in Chapter IX), although possibly helpful in this regard, is not likely to substantially reduce the climate of uncertainty facing the domestic copper industry because of environmental regulations.

2. General Issues Pertaining to the Future of the Domestic Copper Industry

The following general conclusions are suggested from the foregoing discussion and findings:

a. Growth of the Domestic Copper Industry

The constraint on domestic smelter capacity growth imposed by the presently promulgated federal environmental regulations plus continuing future uncertainty regarding new regulations and the way they will be enforced will quite likely slow down domestic smelter capacity expansion and new resource development generally.

b. Technological and Energy Implications

The federal regulations affecting the copper industry are more complex than those affecting even larger industries (e.g., iron and steel, or steam-electric power utility industry, etc.), which is in part due to the apparent desire to force technological change away from reverb-based technology towards new smelting technology more amenable to sulfur dioxide emissions control via the use of sulfuric acid plants. Although this new smelting technology is more energy efficient than reverb-based technology as far as smelting is concerned, the higher degree of pollution control offsets this advantage.

c. Substitution of Aluminum for Copper

Aluminum prices could increase relative to copper prices, because of the actions of the major bauxite producing countries (e.g., increased taxes, cartelization, etc.) or because of higher energy costs. This may slow down the substitution of aluminum for copper but not necessarily stop it, especially because domestic copper prices would also rise because of compliance costs and constraints on domestic capacity growth.

In the past, the process of substitution has been a gradual one, limited in its pace by the fixity of the machinery and equipment in the short-run, the need for process-design changes requiring virtually irrevocable, heavy investments in new machinery and equipment and a desire to avoid risks associated with high degree of maintenance costs in new applications.

Compared to copper, which has been estimated to require between 86 and 112 million Btu/ton product[8], aluminum ingot production is estimated to require twice as much energy per net ton product (i.e., 244 x 10^6 Btu's per ton product)[9]. It has often been remarked, as a result, that the higher energy content of aluminum, together with stronger threats of a bauxite cartel[10] would tend to virtually bring to a halt further substitution of aluminum for copper.

Further increases in aluminum prices induced by higher energy costs could slow down but would not necessarily put a stop to substitution from aluminum. Also, regarding the implications of bauxite cartelization on the substitution of aluminum for copper, it should be noted that recent activities by several important producers of bauxite, the major ore used to produce aluminum, have led to a doubling of price[11]. However, because the cost of ore is only a small portion of the total cost of producing aluminum (about 10 percent), larger movements in bauxite prices would be required to significantly influence aluminum prices.

An important end-use market where furhter substitution could take place is power transmission and distribution cables. Aluminum has already claimed the majority of the market for overhead transmission cable and for distribution cable. Further, it has made considerable inroads into the distribution wire market. While house wiring appears to face serious problems[12], telephone conductor cable and automobile radiator applications pose perhaps the most serious threat to metallic conductors in the telephone wire market which is currently a large end user of copper.

3. International Economic Implications[13]

Both the capacity constraints imposed domestically by recent EPA regulations and costs of compliance with these regulations may have significant international economic implications beyond those noted above pertaining to international trade effects. A series of basic questions arise in this context:

- What will be the effects of domestic environmental regulations on the long-run competitive position of the United States copper industry?
- What are likely to be the effects of domestic environmental regulations on the domestic as well as international investment behavior of United States primary copper producers?
- What effect, if any, would domestic environmental regulations have on the future structure of the world copper market?
- What are the prospects for the cartelization of the world copper market (outside the United States) and/or for the emergence of commodity access agreements for controlling the world price of copper? What are the potential implications of such developments for United States dependence on external sources of copper?

We have investigated these and similar questions in some depth as part of this study. Summarized below are our major findings.

a. Effects of the International Competitive Positions of the United States Copper Industry

The international competitive position of the domestic copper industry will be negatively affected but perhaps not as significantly as would be suggested by the foregoing findings, mostly because of mitigating factors in the rest of the world expected to have a substantial influence on costs of production abroad. Among these factors can be cited differential impacts of energy price increases, expected high rates of inflation not offset by exchange rate adjustments, high infrastructure investment requirements, generally lower labor productivity, and a growing set of requirements by international financing institutions (e.g., the World Bank) for pollution control at new projects.

A comprehensive assessment of the potential effects of domestic environmental regulations on the international competitive costs of production internationally, (b) information on foreign environmental regulations and estimates of compliance costs on a basis comparable with similar information for the United States, and (c) consideration of pollution acceptance as a resource in international trade.

First, comparable data on costs in the copper industry in various countries of the world are very difficult to obtain and to interpret in terms of relative competitive advantage. For new large mines, capital costs tend to be somewhat similar because the technical conditions of production are much the same. On the other hand, infrastructure costs incurred by the copper producing firm may differ substantially. Project costs may differ, depending on the degree of pollution control at new projects that is required by financing institutions (e.g., the World Bank).

Interest costs may differ, depending upon how the financing has been arranged. Labor costs may account for one-third to one-half of operating costs, depending upon whether the mine is an open-pit or underground operations, since the latter type operation is more labor intensive. Wages and labor productivity are important determinants of cost. Rapid increases in wages (such as have occurred in Peru and Central Africa) which are not offset by exchange rate depreciation or rapid increases in energy costs may shift a low-cost mine into a high-cost category within a few years. Differences in the quality of the ore may be offset by the existence of co-products, such as gold, the price of which has increased several-fold in recent years[14].

The five-fold rise in international oil prices has changed relative costs substantially throughout the world, depending upon the source of energy used in the production and transportation of copper. For example, the rise in oil prices was largely responsible for shifting the Philippine mines from relatively low-cost producers to a high-cost category. Capital and operating costs are also affected by environmental regulations. Finally, royalties, excise taxes (which are usually included in production costs), and corporate income taxes introduce complexities in determining comparative costs, since these charges have a different impact on government-owned mining enterprises as contrasted with privately-owned mines.

We expect the relative cost positions of the various copper producing countries will change over the next five years, with differential rates of domestic inflation not offset by exchange rate adjustments and by differential energy costs (e.g., the development of cheap hydroelectric power in Zaire and exploitation of South African coal reserves). Despite the low grade of United States copper ore, a narrowing of the cost differential between the United States (and Canada) and other regions of the world is generally expected in the future for a number of reasons. Some of the most important reasons are : (1) labor costs in North America are expected to rise at a slower rate than elsewhere; and (2) the United States and (especially) Canada are likely to be less adversely affected by the future rise in energy prices[15]. Some of these reasons may require further examination, however.

Second, comprehensive and comparable information on foreign pollution abatement standards and compliance costs are lacking to permit quantitative cost comparisons. Information on European countries with smelters--principally Belgium, West Germany, Norway and Sweden--indicates that their pollution abatement standards are comparable to those in the United States, but that there is more flexibility in their administration, particularly as related to existing local ambient conditions, so that costs may be lower in some cases than for the United States. Japan may have even higher standards but again with greater administrative flexibility. Even before the imposition of strict SO_2 emission standards, Europe and Japan found it profitable to employ smelting techniques that captured a high proportion of SO_2 for production of sulfuric acid[16].

Pollution abatement standards in developing countries vary but are generally lower than in the developed countries. This is in part because most of the smelters in Africa and Latin America are located far from populated areas. Despite the desire of the developing countries to process their own ores by building smelters or encouraging foreign investors to do so, it seems likely that most developing countries will over time insist on pollution abatement standards but perhaps with allowance for the ambient conditions and population.

Some of the new mine development agreements between host government and foreign companies provide for observance by the foreign companies of environmental regulations, but without providing details regarding those regulations. For example, Anaconda has been building a pyrometallurgical smelter in Brazil under contract with a Brazilian government enterprise, which calls for the same type of pollution abatement standards as in the United States. The World Bank Group has been encouraging its members to adopt environmental standards in the formulation of the projects for Bank financing, and in some cases has insisted on the incorporation of pollution abatement facilities in such projects[17].

Finally, we should consider the implications, for the competitive position of the United States copper industry, of the willingness elsewhere in the world to accept pollution (or to tolerate lower standards of pollution abatement) as a national resource which will affect the country's comparative advantage in international trade. It is argued that if certain countries are willing to accept more pollution than others, they will gain a relative advantage in producing those commodities which involve pollution in their production and whose costs of pollution abatement tends to be high[18]. This advantage may also occur because of the profitability of locating high-polluting production in certain countries in areas far from populated centers (e.g., the location of copper smelters in the deserts of northern Chile). One possible mitigating factor would be the possibility of changing the technical conditions of production for any particular commodity toward the use of non-polluting processes, so that over time non-polluting technology becomes competitive with polluting technology. However, new non-polluting alternatives to copper smelting, such as the hydrometallurgical processes for treating sulfide concentrates are currently not cheaper than the pyrometallurgical processes. Over time pollution abatement standards are likely to become more important in the developing countries, thereby reducing their relative advantage.

b. Effects on the Investment Behavior of United States Primary Copper Producers

There exists a virtual concensus in the industry that differences among various countries in terms of pollution control costs alone are likely to prove quite insignificant in their decisions regarding new investment abroad compared with the large number of uncertain factors associated with foreign investment in most developing countries. Further, political risks abroad are generally assigned greater weight than environmental risks faced at home. Nevertheless, there is a growing climate of opinion that political risks abroad are controllable through international financing, joint ventures, majority ownership in the host country, and other means. Accordingly, there appears to be emerging the view that the cycle of expropriation abroad is at an end, whereas the end of environmental regulations in the United States is nowhere in sight. Hence, new investment is likely to be exported abroad to areas which are considered less risky politically. The recent growth in copper production capacity in Canada takes on new significance when viewed in this light. The Canadian copper industry, which will be a major beneficiary of the capacity constraint in the United States, is expected to emerge as a major exporter of copper to the United States.

In a perfectly competitive world economy with no constraints on foreign investment, a decline in the profitability of an industry in the United States [illegible]ng from increased total unit costs alone would tend to shift [illegible]stment in that industry to other industries or countries where costs have not risen. In other words, lower rates of return in the domestic industry would reduce the amount of domestic capital available for reinvestment in that industry, while higher rates of profitability abroad would increase foreign capital available for investment in other countries. Further, higher costs in the United States, accompanied by a constraint on domestic capacity growth, would in the long-run tend to bring about upward pressure on world prices; as a result, expected profitability in foreign areas would tend to rise, leading to an acceleration in the outflow of investment abroad. The pace of such an investment outflow would be offset by the degree to which domestic producer prices remain high enough in view of rising prices in the rest of the world, to enable domestic producers not only to cover their increased costs of production but also to attain a return on their invested capital sufficient to induce further investment domestically.

c. Implications for the Future Structure of the Copper Industry

Domestically, the presently promulgated federal environmental regulations would quite likely slow down or delay the entry of new firms (e.g., oil companies) into the industry, thus possibly reversing an evolving trend during the postwar period when the industry has become increasingly more diverse and perhaps less concentrated. Worldwide, the effects might be just the opposite, in the sense that the constraint domestically on capacity growth may spur investment abroad especially as LME copper prices rise over the next five-to-seven years in response to not only a secular upward shift in worldwide demand but also, and in particular, as a result of the constraint on capacity growth in the United States.

In this respect, it should be noted that the long-run supply factors, rather than demand factors, are likely to be the more crucial, in terms of the future structure of the world copper industry, given the relative inelasticity of demand for copper and even after allowing for continued long-run substitution from aluminum.

On the supply side, we should dwell briefly on known world reserves, already discussed in Chapter V. Reserves are not static but change with the amount of exploration activity, technology and the price of copper; the lower the grade of the ore and the higher the cost of extraction (all else being equal), the higher must be the price for its recovery to be profitable. Based on available data (see Chapter V) identified and potential copper world reserves are in excess of a billion tons of copper content, more than three times the estimated cumulative world consumption of copper between now and the year 2000. Hence, it is most unlikely that aggregate world reserves will constitute a constraint on output in the foreseeable future. On the other hand, reserves could constitute a constraint on output in particular producing areas over the next several decades and this is more likely to be the case in the absence of adequate exploration activity for identifying additional reserves.

Next, nearly two-thirds of known world reserves are located outside the United States, mostly in the less developed countries (LDCs). In virtually all foreign copper exporting countries, except Canada, the copper content of the ores is substantially higher than in this country, and it is likely that the differential in metal content will increase over time. There are, of course, a large number of other factors which have a bearing on cost and, perhaps more important, the rate at which copper resources can be developed. The shift in ownership and control patterns in the mining industries of the developing countries and the declining role of the international mining companies in exploration and development in these countries have made it difficult to assess the reasons for relative rates of increase in copper producing capacity abroad.

The LDCs are anxious to develop their mineral resources in order to expand their export earnings, and they recognize the need for the technical knowledge, venture and debt capital, and managerial ability of the international mining firms. A case can be made for some countries that exploration and new investment have been curtailed by the nationalization movement. However, it would be rash to predict that the growth of copper mining activity will be substantially retarded in the developing countries as a consequence of the nationalization movement and of the emergence of new relationships between the host countries and the foreign investor. In fact, most of the governments of the copper exporting countries have ambitious plans for expanding their copper producing capacity and these plans may be pushed without regard for the outlook for profitability as ordinarily perceived by private enterprise, provided the capital can be obtained. As noted in Chapter VIII, the LDCs have a high foreign exchange requirement to finance their development and for reasons already explained in Chapter VIII, these countries could continue to expand copper production even in face of low LME prices. Moreover, governments are not subject to the kinds of constraints on investment in new capacity imposed by high taxes, government regulations, and political instability that deter private investors.

However, there are serious difficulties facing many foreign countries in obtaining the necessary technology, management and capital from abroad for realizing their national plans for resource development. Some important questions still remain basically unresolved. First, will there be an adequate expansion of exploration in the developing countries? Will host governments be able to raise the billions of dollars required to develop their mineral reserves as majority or 100 percent owners and managers? Will the host governments be able to maintain or attract the technical and managerial personnel needed for the efficient operation of existing mines and the expansion of their productive capacity?

The answers to these and other questions, such as those relating to the effects of nationalization on world markets, will have an important bearing on the long-run supply of copper. However, in this context, it seems quite likely that for the present and for some years to come, the development of new mining capacity, particularly in the developing areas, will depend upon management and technology provided by the large international mining companies and upon the ability of these companies to raise large amounts of capital, running into many billions of dollars, from outside sources.

d. Prospects for Cartelization and International Commodity Agreements

In recent years there has been a great deal of discussion and theorizing regarding the international control of copper prices. The purpose of control arrangements might be simply to avoid sharp fluctuations in world copper prices that prove uneconomic and harmful to producers and consumers alike. The objective of such an effort would be to maintain the price of copper close to its long-term equilibrium level as determined by long-run cost and demand factors. Alternatively, the purpose might be to maximize the copper earnings of the developing countries, since the developing countries account for the vast bulk of the primary copper produced outside the United States and nearly all of this copper is exported.

Recently, serious concern has been expressed that the present members of CIPEC, an organization involving all of the major copper exporting countries, might act in concert to double or triple the world price of copper, much in the same way that OPEC has tripled the price of petroleum over the past three to four years. However, CIPEC, while patterned after OPEC--the oil cartel--, has not yet evolved a mechanism to control prices or, far short of that, to stabilize prices through an international buffer stock arrangement.

The gains and losses to the producing and consuming countries arising from an international price stabilization program through, for example, a copper buffer-stock arrangement is not entirely clear. At any rate, the subject is sufficiently complex to warrant separate examination, especially in view of the current deliberations internationally in connection with the Integrated Program for Commodities proposed by UNCTAD[19].

As far as the threat of cartelization is concerned, it should be noted that, in principle, collusive control of copper prices would help to maintain or raise prices over relatively short periods. However, the higher disequilibrium prices would soon invite increased primary copper production, some increase in the supply of secondary copper, and the substitution of other metals for copper in important uses. This means that, in the future, any rational undertaking by CIPEC to control copper prices must take into account the intermediate and long-term effects on the foreign exchange earnings of its member countries and not simply its ability to influence prices in the short-run.

In the normal course of events in the future, the likelihood of the emergence of a CIPEC cartel would not appear to be high. This can be seen by briefly examining the similarities and differences between CIPEC and OPEC. Most fundamentally, CIPEC's world market power in copper differs from that of OPEC's in petroleum in several important respects. First, world petroleum reserves are heavily concentrated in the Middle East, and at the rate of growth of world petroleum demand in 1970-1972, nearly half of the required annual increase in output over the next decade would have to come from one country, namely Saudi Arabia. Copper resources on the other hand are more widely distributed throughout the world, and the CIPEC countries account for a much smaller share of world copper exports than do the OPEC countries of the world petroleum exports. Second, substitutes for primary copper, including scrap and other metals, are more readily available in the short- and intermediate-run than are substitutes for petroleum for meeting the world's energy requirements. Withholding the oil output of two or three Arab states could substantially impair the economies of Western Europe and Japan. Withholding all of CIPEC's copper output would inconvenience the world economy but not seriously reduce the world's industrial and agricultural production. Third, several of the Arab oil states have producing capacity that substantially exceeds their need for foreign exchange over the next few years, and at current levels of production they are accumulating reserves on a massive scale. This is not true for any of the CIPEC countries, all of which desire to expand output and develop their copper reserves for meeting their foreign exchange requirements. This factor is important for attempts to control output and productive capacity of copper over the longer-run. Some of these factors would operate to limit CIPEC's market power even if the organization were expanded to include all of the major copper countries in the developing world and if they were able to unite on a common program for market control.

Nevertheless, the likelihood that an expanded CIPEC will be able to exercise some control over the world price of copper in the medium-term future cannot be ruled out. Such a development could occur especially if worldwide macroeconomic recovery becomes strong. In this event, the CIPEC member countries would experience an improvement in their payments deficits resulting from higher prices. This would ease the pressure on them for competitive pricing among themselves to obtain badly needed foreign exchange.

In the longer-run, all copper producing countries would probably want to obtain a larger share of the world market; hence, it is most unlikely that there will be any agreement on sharing the growth in copper producing capacity over the long-run. At any rate, even if CIPEC were able to achieve somewhat greater price stability in the medium-term through the operation of a buffer stock, or otherwise, the long-run average price of copper might not be greatly affected. Moreover, if the average price of copper were raised, revenues might not rise because of competition from substitutes for primary copper, including scrap copper, aluminum and plastics.

CHAPTER XII

NOTES

1. For a review of how the cost schedules are affected by compliance costs, refer to Technical Appendix to this report, Econometric Simulation and Impact Analysis Model of the U.S. Copper Industry, Supporting Paper 5: "Effects of Pollution Abatement and Control Costs on Industry-Wide Cost Functions".

2. Refer to Technical Appendix to this report, Econometric Simulation and Impact Analysis Model of the U.S. Copper Industry. The model is econometrically estimated (including demand functions, investment/capacity expansion behavior, supply functions for the competitive secondary copper sectors, inventory equations, etc.) by using a combination of 2SLS with a correction for autocorrelation (iterative Cochrane-Orcutt technique, augmented by the use of the Hildreth-Lu scanning technique when the former led to a local, rather than a global, minimum of the sum of squared residuals).

   The model is mathematically solved by developing and using a modified version of the Newton-Raphson technique where the solution is made essentially independent of the initial guess for the root.

   The financial analysis module is block-recursive with respect to the econometric model. Overall cash-flow and flow-of-funds (sources versus uses) analyses are performed, by analyzing financial data computed directly from the model's results, as well as on the basis of detailed historical industry-wide and specific company-by-company financial data. Various types of standard financial checks are exercised, by examining debt-to-equity ratios, amount of external borrowing required, profits on sales, rate of return on assets, and so forth.

3. The employment forecasts discussed here reflect average labor productivity (refined copper output by the primary producers per full-time equivalent employee) conditions prevailing over the period 1967-1973 (actual, estimated productivity levels were used for years 1974-1977). Overall labor productivity in the domestic copper industry has at best remained fairly constant in recent years. Employment forecasts reflect no significant improvement in labor productivity over the 1978-1987 period. To the extent that the industry's productivity problem further deteriorates, the employment impacts given here would understate potential impacts.

4. Possible layoffs would be associated, under this analysis, only in the eventuality that the McGill, Douglas, and Tacoma smelters would be closed down as assumed under the Reduced Capacity scenario.

5. The employment data given here are obtained from United States Bureau of the Census, Census of Manufactures, 1972, Industry Series: Smelting and Refining of Nonferrous Metals and Alloys. Vol. II, 33C (Washington, D.C.: United States Government Printing Office, 1975) Table 2. It should be noted that employment data at the state level (except for Arizona) are withheld to avoid disclosing figures for individual companies.

6. For a detailed discussion of the points made here, pertaining to the cost functions of the primary producers, refer to Technical Appendix to this report, Econometric Simulation and Impact Analysis Model of the United States Copper Industry.

7. We have discussed in Chapter X in considerable technical detail how the present environmental regulations effectively constrain domestic capacity growth. In retrospect, this result appears to have been unintended.

8. Cement copper (86); refined copper (112), with the following breakdown: mining (21.6), at 0.2 percent grade with 157 tons of ore per ton metal; concentration (42.3); smelting (38.2); refining (10.2). This high energy consumption stems from problems associated with the relatively low grade of the ore. See Earl T. Hayes, "Energy Implications of Materials Processing", Science (Materials) Vol. 191, No. 4228 (20 February 1976), pp. 661-665.

9. Ibid.

10. The reference here is to the International Bauxite Association (IBA), established in a meeting in Conakry, Guinea, March 5-8, 1974; seven founding members include Australia, Guinea, Guyana, Jamaica, Sierra Leone, Surinam and Yugoslavia; headquartered in Kingston, Jamaica. In a Council of Ministers Meeting of the organization held in Georgetown, Jamaica (November, 1974), three new members (Dominican Republic, Ghana and Haiti) were admitted; three other countries (Greece, India, and Trinidad and Tobago) were accepted as official observers. It was also decided that Indonesia and Malaysia would qualify as observers if they should apply. IBA controls about 80 percent of world bauxite production.

NOTES
(Continued)

11. Jamaica unilaterally proceeded to institute a new levy of 7.5 percent of the realized price on sale of primary aluminum and increase royalties to 50 cents per ton of bauxite mined. The Government also purchased a 51 percent equity in Kaiser Bauxite Company and has presumably the same ownership in Revere Jamaica Aluminum, Ltd. Surinam has signed a letter of intent with Alcoa, according to which levies on one ton of bauxite (estimated at $2.50) would be increased to $9. In Haiti, Reynolds agreed to pay increased levies similar to those in Jamaica. See L. Nachai (United States Bureau of Mines), "Investment for Mineral Exploration and Development in Foreign Countries--Problems and Positive Factors", paper presented at the AIME Annual Meeting, Las Vegas, Nevada (February 22-26, 1976), pp. 6, 7.

12. Certain practical difficulties stand in the way of significant substitution of aluminum for copper. For example, with copper wire it is very easy to make connections, while with aluminum considerable care is needed. Also, since aluminum "creeps" more than copper, slack can develop in connections, which can lead to a build-up in resistance in the circuit. This poses a subsequent fire risk by promoting oxidization of the metal and causing a rise in the temperature. Difficulties with installation and with fire risks have led to outright bans of aluminum wire in several areas, notably in California and Washington, D. C.

13. The discussion presented here draws upon working papers and unpublished material provided by Raymond F. Mikesell, Professor of Economics, University of Oregon (Eugene, Oregon); he remains, however, blameless of the interpretation of his inputs and the conclusions drawn by Arthur D. Little, Inc.

14. When the Bougainville mine in Papua, New Guinea went into operation in 1972, the high gold content of the ore helped in making that mine a relatively low-cost producer.

15. See, for example, Commodities Research Unit (CRA), The Current Costs of Producing Primary Copper and Future Trends (1976).

16. This was in contrast to smelters in the Western United States which until recently at least, did not have any outlet for the acid.

17. See Environment and Development, World Bank, Washington, D. C., June 1975.

18. See Ingo Walter, "Environmental Control and Patterns of International Trade and Investment: An Emerging Policy Issue", Banca Nazionale del Lavoro Quarterly Review (March, 1972); Anthony Y. C. Koo, "Environmental Repercussions and Trade Theory", The Review of Economics and Statistics (May 1974); and Wassily Leontief, "Environmental Repercussions and the Economic Structure: An Input-Output Approach", The Review of Economics and Statistics (August 1970).

19. The resolution of UNCTAD IV held in Nairobi, May 1976 for the "Integrated Program" (IP) called for both the stabilization of commodity prices and the improvement of the real incomes the LDCs derived from commodity exports. The IP proposal recommends focus on 17 commodities which cover about three-fourths of the nonfuel commodity trade of the developing countries. These include ten "core" commodities (cocoa, coffee, copper, sugar, cotton, jute, rubber, sisal, tea and tin) and seven others (bananas, bauxite, beef and veal, iron ore, rice, wheat and wool). The ten core commodities are storable and are recommended for initial individual international stockpiling agreements. The UNCTAD IV resolution provides for (1) a negotiating conference on a "common fund" for financing the stabilization arrangements (beginning by March 1977); (2) preparatory meetings on individual commodities not later than February 1978; and (3) commodity negotiating conferences with negotiations to be concluded at the latest by the end of 1978.

For a summary of some of the analytical issues associated with international commodity price stabilization programs, see Raymond F. Mikesell, "The Ford Foundation Sponsored Conference on Stabilizing World Commodity Markets", an unpublished paper which provides a summary of the papers and discussion given at a conference on Stabilizing World Commodity Markets held at Airlie, Virginia, March 17-20, 1977. (Note: the conference was financed by the Ford Foundation and directed and organized by Professor F. Gerard Adams of the University of Pennsylvania).

APPENDIX A

DESCRIPTION OF THE BUSINESS OF THE MAJOR UNITED STATES COPPER PRODUCERS

1. Amax, Inc.

Amax is one of the largest diversified, multinational, nonferrous metals and mineral resources companies. Principal products are molybdenum, aluminum, iron ore, coal, copper, lead, zinc and potash. It also produces nickel, zirconium and other specialty metals.

In July, 1972, Amax acquired Banner Mining Company, which owned the Twin Buttes/Pima County, Arizona property then leased to and mined by Anaconda; and then entered into a partnership arrangement with Anaconda to develop and expand operations at Twin Buttes, with an expected expenditure exceeding $200 million over the period 1973-1976. Banner Mining was acquired in 1973, by merger into Amax Copper Mines, Inc., a wholly-owned Amax subsidiary, in accordance with the plan of merger and partnership.

The Twin Buttes Mine is now owned and operated by Anamax Mining Company, the 50-50 partnership between Amax and Anaconda. The $275 million expansion program is expected to raise capacity from about 75,000 tons/year to 90,000 tons/year (from sulfide ores) plus 36,000 tons/year from a hydrometallurgical process for producing cathodes from oxide ores.

Amax's subsidiary, United States Metal Refining Company, has operated for many years a copper smelter and refinery at Carteret, New Jersey, capable of producing refined copper from domestic and foreign ores, concentrates, blister copper, and copper scrap. The Carteret smelter treats blister copper originating largely from foreign sources, purchased from Amax's own account and on toll for others. It also processes a large volume of scrap, and also treats precious metal-bearing secondary material and precious metal from primary sources both for its own account and for others; large quantities of silver and gold are typically handled. The total annual refining capacity of 275,000 short tons consists of 150,000 tons of electrolytic capacity and 125,000 tons of fire-refined capacity.

An environmental control program for the Carteret plant has been under review by the New Jersey Department of Environmental Protection and EPA, involving the design and construction of additional control facilities. This program is likely to involve cumulative expenditures of $12 to $15 million, most of which has occurred.

Amax had held approximately 20 percent of Copper Range's common stock, and reached agreement in 1975 for Copper Range to merge with a wholly-owned Amax subsidiary. The merger was opposed by the Justice Department and Copper Range was subsequently merged with Louisiana Land and Exploration.

Amax has substantial United States lead and zinc operations, carried out through wholly-owned subsidiaries. It has a participation in a joint venture for the operation of a lead, zinc, and copper mine and mill in

New Brunswick, Canada, through Heath Steele Mines, Ltd., of Canada, also a subsidiary.

Amax and Homestake Mining Company are equal partners in the mine-mill-smelter complex associated with mining of their lead deposits with zinc content, in Southeastern Missouri. The mine participants sell a portion of their lead concentrates under long-term and spot contracts. In October 1969, Amax became a coal producer through the acquisition of Ayrshire Collieries Corporation. In 1974, Amax ranked as the fourth largest coal producer in the United States, up from eleventh position at the time of its entry into the business.

Amax Inc. holds a 50 percent interest in Alumax Inc., formerly Amax Aluminum Company, Inc. Since January 30, 1974, Alumax's outstanding capital stock has been owned equally by Amax Inc. and Mitsui & Co., Ltd., Tokyo. Mitsui paid $135 million cash for its 50 percent interest. In January, 1975, the corporate name was changed to Alumax Inc.

Alumax produces primary aluminum, semifabricated and fabricated aluminum products, architectural products, secondary aluminum and zinc alloys. It operates 49 domestic plants and warehouses located in 24 states, and 14 foreign plants and warehouses located in Canada, Mexico, England, Holland, Germany, France and Sweden.

Table A-1 presents details on the breakdown of Amax's sales revenues and consolidated income, by lines of business, for the past ten years, as reported by the company. Base metals per se, including tolling services and trading revenues, were $607 million in 1974; they typically have accounted for somewhat over 50 percent of total sales, but less than 25 percent of operating earnings ($76 million in 1974, out of $146 million total). Copper sales have accounted for about 17 percent of total sales in recent years, and roughly 75 percent of this is derived from scrap and/or foreign blister. Amax additionally derives revenues from its International Group, including fees and commission through RST International, Inc. ($32 million) and dividends from investments principally in African copper mining companies ($18 million).

2. The Anaconda Company (Atlantic Richfield)[1]

The Anaconda Company was incorporated in the State of Montana in 1985. Anaconda is the third largest producer of primary copper, the largest producer of brass mill products in the United States, and is a significant producer of wire mill products.[2] In addition to mining and processing copper, it has a significant position in the production of aluminum and the mining and milling of uranium.

Anaconda conducts its mining, processing and manufacturing operations at over 50 locations throughout 22 states of the United States, and has 120 sales offices throughout the country. It also has investment in mining, processing and manufacturing operations in Australia, Brazil, Canada, Jamaica, Mexico, Puerto Rico and the Netherlands.

TABLE A-1

AMAX TEN-YEAR FINANCIAL SUMMARY

For the Year[a] (dollars in millions except per share amounts)	1974	1973	1972	1971	1970	1969	1968	1967	1966	1965
Sales	$1,163	$ 964	$ 566	$ 480	$ 582	$ 474	$ 342	$ 273	$ 356	$ 305
Earnings from operations	$145.5	$115.8	$ 71.3	$ 48.9	$ 69.3	$ 48.0	$ 38.8	$ 27.4	$ 50.5	$ 46.7
Equity in earnings of Alumax Inc.	18.9	17.3	10.5	7.2	8.9	12.0	11.0	9.3	8.0	2.1
Interest expense[b]	(22.0)	(26.9)	(21.0)	(25.8)	(19.7)	(10.8)	(8.5)	(6.8)	(6.1)	(4.3)
Interest and other income, net	41.2	16.8	15.9	26.1	22.0	12.8	10.1	9.2	8.0	12.1
Dividend income	19.4	14.2	8.0	11.2	14.2	32.8	28.0	21.9	23.9	22.3
Federal and foreign income taxes	(54.6)	(32.1)	(18.5)	(12.5)	(22.1)	(12.8)	(10.7)	(4.4)	(15.2)	(16.4)
Earnings before extraordinary items	$148.4	105.1	66.2	55.1	72.6	82.0	68.7	56.6	69.1	62.5
Extraordinary items	-	-	-	(3.8)	-	-	7.6	3.5	-	-
Net earnings	$148.4	$105.1	$ 66.2	$ 51.3	$ 72.6	$ 82.0	$ 76.3	$ 60.1	$ 69.1	$ 62.5
Dividends declared on:										
Preferred stock	$ 9.3	$ 10.1	$ 4.1	$ 3.4	$ 3.2	$ 1.2	$ .4	$ .9	$ 1.4	$ 1.8
Common stock	39.0	35.0	33.2	33.1	33.1	31.3	29.4	28.6	28.1	24.3
Total	$ 48.3	$ 45.1	$ 37.3	$ 36.5	$ 36.3	$ 32.5	$ 29.8	$ 29.5	$ 29.5	$ 26.1
Per share of common stock										
Primary earnings[c]	$ 5.82	$ 4.03	$ 2.62	$ 2.03	$ 2.93	$ 3.47	$ 3.28	$ 2.62	$ 3.06	$ 2.78
Fully diluted earnings[c]	5.26	3.74	2.59	2.00	2.83	3.40	3.20	2.55	2.94	2.67
Dividends declared	1.64	1.48	1.40	1.40	1.40	1.33	1.27	1.27	1.27	1.12
Dividends as a percent of primary earnings	28%	37%	53%	69%	48%	38%	39%	48%	42%	40%
Book value	$31.72	$27.50	$25.75	$24.54	$23.91	$21.14	$19.97	$17.85	$16.13	$14.13
Price range high	$52-7/8	$51-1/4	$33-7/8	$37-3/8	$40	$37	$35-5/8	$38-3/4	$43-5/8	$36-1/8
low	$30-1/4	$29	$27	$25-1/4	$28-3/4	$29-1/8	$28	$28-1/8	$22-3/4	$26-7/8
Price earnings ratio	9-5	13-7	13-10	18-12	14-10	11-8	11-9	15-11	14-7	13-10
Return on January 1, shareholders' equity	17.7%	15.2%	10.0%	7.9%	12.5%	17.3%	17.9%	15.0%	19.6%	19.8%
At Year-End[a] (in millions)										
Working capital	$ 197	$ 327	$ 339	$ 299	$ 217	$ 191	$ 197	$ 194	$ 172	$ 167
Investments (at book amounts) in:										
Alumax Inc.	130	206	203	218	207	201	185	145	128	98
Africa	90	61	85	79	83	62	52	42	40	38
Other	52	42	50	38	38	35	26	28	21	20
Property, plant and equipment (net)	1,069	771	574	485	397	332	213	182	173	147
Long-term debt	(401)	(441)	(457)	(391)	(260)	(201)	(190)	(157)	(126)	(108)
Deferred income taxes	(109)	(77)	(64)	(42)	(30)	(27)	(15)	(14)	(14)	(11)
Other	(86)	(49)	(37)	(22)	(3)	(10)	7	7	0	1
Shareholders' equity	$ 942	$ 840	$ 693	$ 664	$ 649	$ 583	$ 475	$ 427	$ 394	$ 352

NOTES: [a] Previously reported amounts have been restated to include Alumax, Inc. on an equity basis.

[b] Effective October 1, 1971, the capitalization of interest applicable to major construction projects was extended to include interest on general corporate borrowings, as well as specific project borrowings. Interest capitalized totaled: 1974, $17.0 million; 1973, $14.0 million; 1972, $11.6 million and 1971, $3.8 million. No interest was capitalized in 1970 and interest capitalized in prior years was not material.

[c] Includes extraordinary gains and charges: 1971, charge of 16¢ per share; 1968, net gain of 33¢ per share; 1967, gain of 15¢ per share.

SOURCE: Amax Annual Report.

TABLE A-1
(Continued)

AMAX TEN-YEAR FINANCIAL SUMMARY--BY LINES OF BUSINESS

For the Year (dollars in millions)	1974	1973	1972	1971	1970	1969	1968	1967	1966	1965
Sales:										
Molybdenum and Specialty Metals	$ 240	$ 179	$ 114	$ 108	$ 145	$ 155	$ 123	$ 106	$ 123	$ 111
Base metals[a]	607	534	256	205	276	275	197	141	200	161
Fuels and Chemicals	206	154	137	118	118	36	22	26	33	33
Iron Ore	78	60	45	39	25	8	-	-	-	-
RST[b]	32	37	14	10	18	-	-	-	-	-
Total sales[c]	$1,163	$ 964	$ 566	$ 480	$ 582	$ 474	$ 342	$ 273	$ 356	$ 305
Earnings from operations before income taxes, exploration and unallocated corporate expenses:										
Molybdenum and specialty metals	$ 41	$ 46	$ 28	$ 28	$ 51	$ 55	$ 37	$ 32	$ 40	$ 39
Base metals	76	47	16	8	11	9	14	9	20	15
Fuels and Chemicals	45	22	23	15	13	0	1	0	4	8
Iron Ore	37	32	25	23	13	4	-	-	-	-
RST	20	26	5	1	8	-	-	-	-	-
	219	173	97	75	96	68	52	41	64	62
Exploration expenses	(37)	(33)	(12)	(16)	(14)	(9)	(7)	(7)	(5)	(7)
Unallocated corporate expenses	(36)	(24)	(14)	(10)	(13)	(11)	(6)	(7)	(8)	(8)
Earnings from operations	$ 146	$ 116	$ 71	$ 49	$ 69	$ 48	$ 39	$ 27	$ 51	$ 47
Capital expenditures and investments:										
Molybdenum and specialty metals	$ 140	$ 51	$ 39	$ 49	$ 29	$ 11	$ 17	$ 25	$ 24	$ 25
Base metals	76	110	10	8	8	15	15	13	9	6
Fuels and Chemicals	89	64	52	36	19	83	4	5	12	7
Iron ore	33	10	8	30	24	18	29	14	1	2
RST	-	1	8	-	84	-	-	-	-	-
Corporate	68	17	28	6	4	10	11	-	2	5
Total capital expenditures and investments	$ 406	$ 253	$ 145	$ 129	$ 168	$ 137	$ 76	$ 57	$ 48	$ 45
Depreciation and depletion	$ 46	$ 37	$ 32	$ 28	$ 26	$ 18	$ 18	$ 13	$ 16	$ 14

NOTES: [a] Includes the sale of metals processed from concentrates and scrap materials, tolling services, sales of copper from AMAX's 50% share of the operations of the Twin Buttes Mine from January 1, 1973 and sales of copper and silver arising out of purchase and sales transactions of these metals on commodity exchanges.

[b] Consists of fees, commissions and net trading revenue.

[c] Sales of molybdenum, copper and coal to total Company sales for the last five years were as follows:

	1974	1973	1972	1971	1970
Molybdenum	20%	17%	18%	20%	23%
Copper*	17	17	19	16	21
Coal	12	10	16	13	10

*Exclusive of charges for toll refining of copper and transactions on commodity exchanges.

Anaconda employed approximately 21,934 persons at July 30, 1975, compared to 27,840 persons employed by it at June 30, 1974. (This substantial reduction in employees resulted from layoffs which were compelled by reduced demand for Anaconda's products during the recession, together with company-wide efforts to reduce costs and increase productivity.

a. Copper Production

Anaconda's domestic production of primary copper was 190,059 tons in 1974. Over the five year period 1970-75, production ranges from a low of 149,600 tons in 1975 to a high of over 200,000 tons in 1970. Approximately 60 percent of such production comes from the Butte Mines in Montana; certain of these operations are being phased out. The Twin Buttes Mine in Arizona, on the other hand, has been the subject of a new development investments, through Anamax Mining Company, a 50-50 partnership between Anaconda and Amax (see also Amax).

Substantially all copper concentrates from Anaconda's mines and precipitates from leaching operations are shipped to its smelter in Anaconda, Montana for smelting. All anode copper produced at the smelter in Anaconda, Montana is shipped to Anaconda's electrolytic refinery at Great Falls, Montana for refining and casting into commercially marketable forms of refined copper, and slimes are set apart for recovery of precious metals.

In October, 1974, production commenced at Anaconda's new Arbiter plant near Anaconda, Montana. The Arbiter plant represents the first commercial application of a hydrometallurgical refining process in the copper industry instead of the traditional combination of pyrometallurgical and electrolytic refining processes. A principal advantage of the new Arbiter process is the elimination of sulfur oxide and other air pollutants produced by the conventional pyrometallurgical smelting of sulfur ores. The Arbiter process was developed by Anaconda's metallurgical research department as a part of a major research effort to reduce pollution.

Anaconda has stated that the Arbiter plant is capable of treating a wide range of concentrate types and grades with a recovery capability approximately equal to the most efficient smelters. Capital costs of a plant using the Arbiter process are estimated to be lower than those of a conventional smelter and refinery, and it is anticipated that the operating costs of the Arbiter plant will be competitive with costs incurred in the conventional method. Anaconda has invested approximately $47 million in the construction and development of the Arbiter plant as of June 30, 1975.

In July, 1975, the Arbiter plant was temporarily shut down, and was reopened in mid-1976, after required adjustments relating primarily to materials handling and mechanical problems. Anaconda spend an additional investment of approximately $8 million for these adjustments. The Arbiter plant is expected to have a capacity of approximately 36,000 tons os cathode copper production per year.

Significant by products are produced in the course of Anaconda's copper processing operations. Molydenite is recovered at the Twin Buttes Mine. Silver, gold, selenium and tellurium are recovered by the refinery from the slimes left in the refining plant after the production of electrolytic copper. Anaconda received approximately $30.3 million from the sale of precious metals in 1974, compared with $15.2 million in 1973.

Approximately 49 percent of Anaconda's mined copper was sold to its manufacturing divisions in 1973, compared to 58 percent in 1974 and 72 percent for the six months ended June 30, 1975, and the balance was sold to others. Approximately 37 percent, 41 percent and 63 percent of the copper required for Anaconda's domestic manufacturing operations was purchased from Anaconda during 1973, 1974 and the six months ended June 30, 1975, respectively, and the balance was purchased from other primary copper producers, scrap dealers, customers and other sources.

b. Sales and Operating Income by Division

Table A-2 sets forth the approximate relative contributions to consolidate sales and operating income by Anaconda's organizational profit centers for the four years 1972-1975. Comparable information for prior periods is not available, primarily because of the Chilean expropriation and subsequent corporate reorganization in 1971. A five-year summary is presented in Table A-3.

c. Foreign Operations

Among Anaconda's foreign manufacturing interests are a wholly-owned subsidiary, Anaconda Canada Limited, which operates a large brass mill in Toronto, Ontario.

Anaconda owns 49 percent of Compania Minera de Cananea, S.A., which has an open-pit mine at Cananea in the State of Sonora, Mexico. The Cananea Mine produced 44,373 metric tons of blister copper during 1974, compared with 41,999 metric tons during 1973. In 1973, an expansion program commenced which is expected to increase production to approximately 70,000 metric tons of copper per year by the end of 1976.

Cananea Mine production is concentrated and smelted at Cananea facilities, and the resulting blister copper is shipped for refining to Cobre de Mexico S.A. in Mexico City, in which Compania Minera de Cananea has a small ownership interest.

Anaconda also owns a 40 percent in National De Cobre, S.A., which operates casting and brass mill manufacturing facilities in Mexico City, a 40 percent interest in S.A. Marvin, which operates a brass mill in Brazil.

TABLE A-2

ANACONDA'S SALES AND OPERATING INCOME BY DIVISION
(millions of dollars)

The following table sets forth the contributions to consolidated sales and operating income by Anaconda's organizational profit centers for the four years 1972-1975. Comparable information for 1971 is not available, primarily because of the Chilean expropriation and subsequent corporate reorganization in 1971.

	1975	1974	1973	1972
Sales and other operating revenue:				
Montana Mining and General Mining Divisions	$ 278.1	378.5	341.3	341.8
Uranium Division	24.0	28.6	29.5	18.2
Natural Resource Divisions	302.1	407.1	370.8	360.0
Aluminum Division	311.2	384.0	276.2	198.4
Brass Division	347.2	616.4	497.3	346.5
Wire and Cable Division	294.1	502.0	390.5	286.1
Walworth Division (Acquired October 1975)	11.6			
Forest Products Division (Sold June 1972)			9.7	24.6
Less sales between divisions	(178.4)	(236.8)	(201.4)	(204.0)
Net Sales and other operating revenue	$1,087.8	1,672.7	1,343.1	1,011.6
Operating income (loss):				
Montana Mining and General Mining Divisions	(40.7)	41.1	49.9	27.2
Uranium Division	.5	4.5	10.1	5.8
Natural Resources Divisions	$ (40.2)	45.6	60.1	33.0
Aluminum Division	17.4	48.9	(2.9)	3.9
Brass Division	(1.8)	30.1	24.9	10.3
Wire and Cable Division	9.2	61.3	23.9	13.8
Walworth Division (Acquired October 1975)	.8			
Forest Products Division (Sold June 1972)				3.6
Unallocated Corporate Expenses	(13.2)	(11.0)	(9.1)	(8.4)
Consolidating adjustments	(.9)	(1.3)	—	—
Operating income (loss)	$ (28.7)	173.6	96.8	56.2

SOURCE: Anaconda Annual Report.

TABLE A-2
(Continued)

FIVE-YEAR SALES BY CLASS OF PRODUCTS
(millions of dollars)

	1975	1974	1973	1972	1971
Copper and copper products	$ 625.1	$1,163.1	$ 960.9	$ 701.3	$ 662.5
Aluminum and aluminum products	335.8	403.8	299.7	220.2	177.0
Uranium oxide	24.0	28.6	29.5	18.2	20.4
Other metals, forest products, etc.	102.9	77.2	53.0	71.9	86.6
Total	$1,087.8	$1,672.7	$1,343.1	$1,011.6	$ 946.5
Primary Production					
Copper (short tons)	149,622	197,543	208,110	242,955	227,415
Aluminum (short tons)	243,591	298,737	217,950	177,618	171,677
Uranium (short tons)	1,736	2,025	2,069	2,022	1,763
Silver (thousands of ounces)	2,352	3,571	4,256	3,979	3,869

SOURCE: Anaconda Annual Report.

TABLE A-3

ANACONDA FIVE-YEAR SUMMARY OF OPERATIONS

(millions of dollars, except per share figures)

	1975	1974	1973	1972	1971
Sales and Other Operating Revenue	$1,087.8	1,672.7	1,343.1	1,011.6	946.5
Operating Costs and Expenses					
Cost of sales and expenses	1,065.2	1,448.4	1,200.6	911.3	882.3
Provision for depreciation and depletion	51.3	50.7	45.7	44.1	46.9
	1,116.5	1,499.1	1,246.3	955.4	929.2
Operating Income (loss)	(28.7)	173.6	96.8	56.2	17.3
Equity in net income of affiliated companies	5.8	16.7	15.3	10.0	4.2
Income from Chilean investments	9.4	5.4			
Interest and miscellaneous income	6.1	5.6	4.8	4.3	1.6
Interest expense	(32.0)	(29.7)	(23.2)	(21.7)	(25.2)
Gains (losses) on foreign exchange	.8	(10.4)			
Income (loss) before Taxes and Extraordinary Income	(38.6)	161.2	93.7	48.8	(2.1)
Provision for income taxes	1.2	54.5	24.6	5.4	3.9
Income (loss) before Extraordinary Income (loss)	(39.8)	106.7	69.1	43.4	(6.0)
Extraordinary income (loss)		140.4	17.7	88.3	(347.9)
Net Income (loss)	$ (39.8)	247.1	86.8	131.7	(353.9)
Per share of common stock:					
Income (loss) before extraordinary income (loss)	$ (1.80)	4.83	3.13	1.97	(.28)
Extraordinary income (loss)		6.36	.80	4.00	(15.89)
Net income (loss)	$ (1.80)	11.19	3.93	5.97	(16.17)
Dividends paid:					
Amount	$ 16.6	22.1	11.0	2.7	10.9
Per share of common stock	$ .75	1.00	.50	.125	.50

NOTES:

[a] Reference should be made to the company's previous annual reports to shareholders for more complete explanations of the extraordinary income (loss) shown above. The extraordinary items included: 1971--losses due to the expropriation of Chilean investments and corporate reorganization costs; 1972--gain on sale of Forest Products Division's principal assets and income tax benefits from utilization of loss carryforwards; 1973--utilization of tax loss carryforwards; and 1974--settlement of 1971 expropriation loss with the Government of Chile and utilization of tax loss carryforwards.

[b] Certain changes in accounting practice were adopted during the five-year period. The only changes significantly affecting reported annual earnings occurred in 1972 in the method of translating foreign currency debt, which resulted in an extraordinary charge of $5.2 million (24 cents per share), and in 1974 in the extension of the use of the Lifo method, which had the effect of reducing income before extraordinary income and net income for that year by $8.9 million (40 cents per share) and $17.2 million (78 cents per share), respectively.

d. Aluminum Division

Anaconda produces aluminum in primary forms from alumina at its reduction plant located at Columbia Falls, Montana, which has an annual capacity of 180,000 tons of aluminum, and its reduction plant in Sebree, Kentucky, which has an annual capacity of 120,000 tons of aluminum. The Sebree facility was phased into operation in mid-1973. Approximately 13 percent of Anaconda's aluminum production was sold to others in 1974.

Anaconda normally receives 59 percent of its alumina (the raw material for producing primary aluminum) from Alumina Partners of Jamaica ("Alpart"), a joint manufacturing venture in which Anaconda has a 27 percent interest. Alpart owns and operates bauxite mines and an alumina production plant in Jamaica, West Indies.

e. Uranium Division

Anaconda has one of the larger uranium mining and milling complexes existing in the United States.

Uranium ore produced from the Jackpile and Paquate mines is processed into uranium oxide at Anaconda's Bluewater plant near Grants, New Mexico. The plant's current milling capacity is approximately 2,500 tons of ore per day. Production of uranium oxide during the five years ended December 31, 1974 and the six months ended June 30, 1975 was about 23 million pounds U_3O_8. Delivery commitments 1976-1980 were expected to approximately equal this amount.

f. Chilean Expropriation

Anaconda suffered the expropriation of its Chilean properties in July, 1971. The Chilean copper mines provided, it is believed, over 40 percent of Anaconda's 1970 earnings and an even greater proportion in prior years. In connection with the expropriation, which has been well publicized, Anaconda's financial statements showed large write-offs, (accounted for as an extraordinary loss) tax credits, and tax-loss carry forward efforts, offset in subsequent years by insurance and Chilean settlement adjustments and their corresponding tax effects.

3. Asarco, Inc.

Asarco's business has, for many years, been in the mining, smelting, and refining of nonferrous ores and concentrates, producing there from principally copper, lead, zinc, silver, and gold, and recovering related by-products from such operations. The business also includes buying and processing nonferrous scrap, and selling the alloys produced; producing and selling coal and asbestos; and producing chemical materials and manufacturing machinery for the metalplating and finishing industry. Asarco's operations are carried on principally in the United States with additional operations in Canada, Mexico, and Peru. Asarco has substantial investment in other mining companies, principally in Australia

(Mount Isa Mines holdings—49 percent), Peru (Southern Peru Copper Corporation--51.5 percent), Mexico (Industrial Minera Mexico--34 percent), and holds a substantial interest in Revere Copper and Brass Incorporated (33.4 percent stock plus convertible debentures).

Table A-4 reproduced from Asarco's Annual report succinctly illustrates Asarco's participation in the nonferrous metals.

In the United States, Asarco plays a special role as the largest custom smelter as well as one handling considerable "dirty" concentrates and recovering by-products such as arsenic. Asarco has incurred substantial expenditures for environmental controls associated with its smelters and refineries.

Asarco has phased out production at its Baltimore and Perth Amboy copper refineries after 1975. Asarco has constructed a new copper refinery, with a designed capacity of 420,000 tons of refined copper per year, in Amarillo, Texas.

The associated companies--principally those in Australia, Peru and Mexico--also have major capital expansion programs underway. Capital expenditures by the three companies in 1972 aggregated $127 million and exploration expenditures exceeded $5 million.

Sales in 1974 totalled $1,344 million, an all-time high. Earnings before taxes and extraordinary items were a record $165.8 million, including $109 million ($43 million in dividends) in equity earnings of nonconsolidated associated companies. A five-year financial summary is presented in Table A-5.

In 1974, Asarco had approximately 15,300 employees. Employment dropped to 13,500 in 1975.

4. Cities Service Company

Cities Service is engaged in finding, producing, manufacturing and distributing oil, gas, and chemical products. The company's annual revenues are in the $3 billion category. Employment totals 17,000 - 18,000.

TABLE A-4

ASARCO AND ASSOCIATED COMPANIES' METALS PRODUCTION

			1975	1974	1973
Copper	Mines	Mission	26,900	40,300	46,600
		Sacaton	21,900	9,500	-
		Silver Bell	18,300	23,500	23,800
		San Xavier	9,700	5,900	2,700
		Granduc[a]	9,300	15,900	16,800
		Quiruvilca	6,200	7,400	8,400
		Others	3,600	4,000	3,100
		Total	95,900	106,500	101,400
	Refineries	Tacoma	119,700	117,400	120,100
		Perth Amboy	117,100	127,600	154,800
		Baltimore	41,800	111,000	138,100
		Amarillo	30,600	-	-
		Total	309,200	356,000	412,800
	Associated Companies	Mount Isa[c]	175,800	167,000	129,300
		Southern Peru[b]	119,600	134,400	133,500
		Industrial Minera Mexico[d]	35,100	37,900	37,100
Lead	Mines	Buchans	11,900	13,900	6,800
		Leadville	7,500	6,400	7,200
		Others	6,000	4,400	4,500
		Total	25,400	24,700	18,500
	Refineries	Omaha	118,200	125,800	136,300
		Glover	81,900	72,900	82,300
		Total	200,100	198,700	218,600
	Associated Companies	Mount Isa[c]	146,700	139,200	125,100
		Industrial Minera Mexico[e]	85,600	108,200	96,600
		Neptune[f]	1,400	3,500	3,000
Zinc (tons)	Mines	Tennessee	47,900	56,400	29,600
		Buchans	19,500	23,400	11,500
		Leadville	14,100	12,800	15,100
		Ground Hog	10,900	12,400	13,500
		Quiruvilca	4,400	4,700	4,900
		Park City[g]	2,700	-	-
		Total	99,500	109,700	74,600
	Zinc Fuming Plants[h]		41,800	39,600	46,700
	Zinc Oxide[i]	Columbus	14,000	20,700	19,200
		Hillsboro	7,200	15,400	13,800
		Total	21,200	36,100	33,000
	Refineries	Corpus Christi	81,900	81,100	88,600
		Amarillo	20,400	46,700	46,800
		Total	102,300	127,800	135,400
	Associated Companies	Industrial Minera Mexico[k]	132,700	135,700	136,400
		Mount Isa[c]	126,600	113,400	112,200
		Neptune[f]	11,700	15,700	20,600
Silver (ounces)	Mines	Galena	3,350,000	3,486,000	4,192,000
		Quiruvilca	1,134,000	1,388,000	1,262,000
		Buchans	611,000	741,000	376,000
		Mission	292,000	511,000	571,000
		Leadville	352,000	330,000	457,000
		Others	711,000	644,000	589,000
		Total	6,450,000	7,100,000	7,447,000
	Refineries	Perth Amboy	44,576,000	37,835,000	45,255,000
		Baltimore	10,679,000	16,947,000	16,130,000
		Total	55,255,000	54,782,000	61,385,000
	Associated Companies	Industrial Minera Mexico[e]	17,303,000	20,770,000	17,225,000
		Mount Isa[c]	11,045,000	9,690,000	8,803,000
		Neptune[f]	98,000	72,000	59,000

NOTES: ACCOMPANYING TABLE A-4

[a] Asarco's 50 percent share of copper in concentrates.

[b] Blister output plus copper exported in concentrates.

[c] Metal content of products for fiscal year ended June 30.

[d] Blister output.

[e] Refined output.

[f] Metal content of products.

[g] Asarco's 40 percent share of zinc in concentrates.

[h] Metal content of zinc fume recovered from lead smelter slag at El Paso and East Helena.

[l] Metal content of zinc oxide.

[k] Refined output plus metal conent of concentrates and fume sold.

SOURCE: Asarco.

TABLE A-5

ASARCO: FIVE-YEAR FINANCIAL SUMMARY

The following tables set forth, for the five years ended December 31, 1975, the approximate amounts of Asarco's[i] consolidated sales and earnings, before taxes on income and extraordinary items, attributable to its principal lines of business and[ii] consolidated sales of principal products and services. Sales figures do not include sales by nonconsolidated associated companies.

Lines of Business	1975		1974		1973		1972		1971	
(dollars in thousands)	Sales	Earnings (Loss)	Sales	Earnings (Loss)*	Sales	Earnings (Loss)*	Sales	Earnings (Loss)*	Sales	Earnings (Loss)*
Primary metals[a]	$ 697,000	$27,493	$1,067,658	$ 78,927	$ 820,692	$ 60,911	$653,706	$27,754	$512,184	$ 8,677
Secondary metals	121,698	3,340	192,395	10,706	137,162	1,467	107,754	1,032	103,587	818
Other products[b]	185,940	(4,489	83,997	824	110,585	(5,257)	52,885	(157)	40,986	800
Equity in earnings of nonconsolidated associated companies[c] ..	-	27,829	-	109,123	-	81,184	-	31,382	-	36,826
Non-operating[d]	-	(18,309)	-	(3,921)	-	(7,108)	-	(3,277)	-	2,268
Unusual items[e]	-	(20,500)	-	(29,838)	-	2,237	-	-	-	-
Total	$1,004,638	$15,364	$1,344,050	$165,821	$1,068,439	$133,434	$814,345	$56,734	$656,757	$49,389

*Restated, see note 2 of notes to financial statements.

Sales	1975		1974		1973		1972		1971	
(dollars in thousands)										
Copper	$ 167,676	17%	$ 290,316	22%	$ 324,671	31%	$263,942	32%	$211,290	32%
Silver	252,634	25	285,176	21	174,083	16	110,534	14	96,798	15
Lead	81,712	8	143,125	11	110,547	10	67,438	8	60,619	9
Zinc	85,893	9	120,866	0	75,697	7	56,232	7	57,623	9
Secondary metals .	121,698	12	192,395	14	137,162	13	107,754	13	103,587	16
Other products[f]	295,025	29	312,172	23	246,279	23	208,445	26	126,840	19
Total	$1,004,638	100%	$1,344,050	100%	$1,068,439	100%	$814,345	100%	$656,757	100%

[a] Includes mining, smelting and refining of copper, silver, lead, zinc and by-products as well as toll treatment charges for smelting and refining.

[b] Primary cost, asbestos and ilmenite.

[c] See note 4 of notes to financial statements.

[d] Primarily dividends and interest on investments (other than those accounted for by the equity method), patent royalties and interest expense.

[e] See note 11 of notes to financial statements.

[f] Includes by-products, coal, asbestos, ilmenite, etc., and toll treatment charges.

Its North American Chemicals and Metals group produced the following tonnages for sale in the last three years:

	1975	1974	1973
	(thousand tons)		
Sulfuric Acid	865	850	910
Copper	47	31	40
Iron Products	284	124	217
Zinc Concentrates	9	6	206
Other Industrial Chemicals	156	161	206

Total sales from North American Chemicals and Metals operations are now in the range of $140-150 million per year, but representing only about 5 percent of the company total, and a somewhat higher percentage contribution to profits. Table A-6 shows financial data for Cities Service.

a. Copper

The Company conducts extensive operations in the "Copper Basin" region of Copperhill, Tennessee. Cities Service commenced its activity there with the purchase of Tennessee Copper Company in 1963. The ore is mined from five underground mines, and contains 35 percent iron, 24 percent sulfur, 1 percent copper and 1 percent zinc. Operations are integrated for production of industrial chemicals and iron products. The values of iron and sulfur recovered at Copperhill are considerably greater than the copper values per se. In 1970, a very large expansion and modernization program was begun, including a new copper smelter, iron oxide pellet plant and an additional sulfuric acid plant. Construction of yet another acid plant was completed in 1975, and completion of two water treatment plants to remove both chemicals and suspended solids from process water is scheduled for 1976.

In addition to operations at Copperhill, much more extensive copper mining operations are conducted at several locations in Arizona as discussed below.

After many years of production, the in-place reserves of the Copper Cities and Diamond H open-pit mines at Miami, Arizona, were exhausted early in 1975, but leaching operations will continue at declining rates for several years.

The mine and mill facilities of the Pinto Valley open-pit mine near Miami, Arizona, were completed in 1974 ahead of schedule and at capital costs slightly below estimates. This represented the largest construction project in the Company's history. The first division began production in June of 1974 and the second division in October of 1974.

TABLE A-6

CITIES SERVICE COMPANY
SUMMARY OF CONSOLIDATED FINANCIAL DATA
(Stated in millions of dollars except per share data)

	1975	1974	1973
CAPITAL EXPENDITURES			
North American petroleum			
Production	151.0	182.4	178.5
Natural gas liquids	10.5	6.9	4.1
Refined products	38.4	49.7	33.2
Alternate fuels	92.5	46.4	4.9
	292.4	285.4	220.7
Natural gas transmission	19.2	16.6	13.6
North American petrochemicals	21.3	19.0	12.5
North American chemicals and metals	50.0	90.5	75.1
International	47.8	28.0	19.6
Other operations	5.2	5.4	54.9
Total plant additions	435.9	444.9	396.4
Investments	3.5	2.0	5.8
Total	439.4	446.9	402.2
PROPERTY, PLANT AND EQUIPMENT			
North American petroleum			
Production	1,354.2	1,253.1	1,124.6
Natural gas liquids	229.5	220.7	215.2
Refined products	697.7	696.5	691.2
Alternate fuels	120.9	52.6	5.5
	2,402.3	2,222.9	2,036.5
Natural gas transmission	394.6	379.5	365.4
North American petrochemicals	325.4	309.2	313.3
North American chemicals and metals	408.2	365.2	281.7
International	68.0	50.8	39.0
Other operations	85.6	84.2	255.5
Total gross investment	3,684.1	3,411.8	3,291.4
Accumulated depreciation and depletion	1,597.4	1,481.0	1,437.6
Total net investment	2,086.7	1,930.8	1,853.8
CAPITALIZATION			
Long-term debt	780.1	581.2	613.8
Stockholders' equity	1,631.8	1,673.7	1,530.1
Total capitalization	2,411.9	2,254.9	2,143.9
Ratio of long-term debt to capitalization	32.3%	25.8%	28.6%
Stockholders' equity at year end, per share[a]	60.46	42.25	56.95
Return on stockholders' average equity--income before extraordinary credits	8.6%	12.7%	9.2%

NOTES: [a] Adjusted for 3 percent stock dividend paid in 1974.

SOURCE: 1975 Annual Report.

The design capacity of 40,000 tons of ore per day was reached early in 1974. This production rate will recover in excess of 60,000 tons of copper annually.

Copper produced in concentrate form will be smelted at a smelter of another company (Inspiration Consolidated).

Start-up of the Miami East underground mine was expected to begin in the early part of 1976, but was postponed due to escalation costs and depressed market conditions. It is believed the production could amount to 2,000 tons of high grade ore per day in 1978.

A solvent extraction-electrowinning plant to produce cathode copper at the Miami leaching operation is under construction and should be completed by mid-1976.

An active mineral exploration program is being conducted in the Rocky Mountain area, in Alaska, and in Canada. The objective is to find deposits of copper and copper-associated minerals.

Cities Service is also engaged in production of fabricated copper products in the form of sheet, strip, and insulated wire. Sales were at record levels in 1974 but volumes have declined in the early months of 1975, reflecting the downward trend of economic conditions. In 1974, a 50 percent expansion was completed at the Chester, New York, plant which manufacturers insulated wire and cable for the electric and electronic industries.

b. Financing

Cities Service has used various sources of funds to supply its capital needs. Earnings and other funds from operations were the major source providing approximately 60 percent of the funds expended on its diverse operations recently. Additional funds were obtained from the sale of $150 million 9-3/4 percent sinking fund debentures and the receipt of $37 million in interest-free advances from natural gas pipeline companies to be repaid from future natural gas production. The Company also raised $48 million by guaranteeing environmental control and industrial development revenue bonds issued by municipal agencies at favorable interest rates for construction of facilities leased to the Company. (The obligations under these leases are recorded as long-term debt in conformity with accepted accounting practices.)

In 1975, Cities Service substantially completed negotiations for an agreement to borrow $100 million from the Province of Alberta, Canada, to help finance development of the Syncrude Canada Ltd. project. The company renegotiated an expanded $200 million line of credit from a consortium of banks. The company issued commercial paper during the year; none was outstanding at year end.

There is a production payment liability on the Pinto Valley orebody which totaled $107.9 million at December 31, 1975. This was a net reduction of $300,000 during 1975 as repayment began from a percentage of the revenues on sale of related copper production.

5. Copper Range Company

Since its organization in 1899, Copper Range Company, a Michigan corporation, and its subsidiaries, have been engaged in the business of mining and refining primary copper in Northern Michigan and, since 1939, in fabricating and distributing copper and brass products. The company is the seventh largest producer of domestic primary refined copper in the United States.

The company's mine, mill and smelter for producing refined copper are located in White Pine, Michigan. Its principal fabricating plant is located in Leetsdale, Pennsylvania, with two smaller plants in Eminence, Kentucky, and Anderson, Indiana. The mine and mill have a capacity of 25,000 tons of ore per day. The company is a relatively high-cost producer. The smelter has a capacity of 180 million pounds of copper per year. The company had approximately 3,600 employees in 1974, but subsequently reduced its work force substantially due to the recession in 1975.

Copper Range has under development a portion of the White Pine mine knows as the Southwest Orebody, in which ore grades are believed to be higher than those in the area currently being mined. In addition to continued development of the Southwest Orebody, Copper Range plans to expand its mining operations in future years by mining, both in the area currently being mined and in other areas, to depths greater than the 2,200-foot level to which mining is now carried out.

The copper produced at White Pine is Lake Copper whose principal distinctive charasteristics is a natural silver content. It is fire-refined and cast at White Pine into standard commercial shapes for sale. The natural silver content of the copper derived from the White Pine mine constitutes a competitive advantage to Copper Range in several markets. In addition, because of its silver content, such copper is sold at prices which include a premium of 1/8 cent of 1/4 cent per pound, depending upon the market on which it is sold. However, the same silver content effectively precludes the use of such copper in wire mills, the largest single market for refined copper, because its heat-resistant qualities require the application of higher temperatures in order to permit such copper to be drawn.

Sales in 1974 were $97.6 million. Refined copper typically has accounted for about 61 percent, fabricated copper products 37 percent, and other revenues 2 percent of sales over the last five years. Sales of copper and prices received for the five years ended December 31, 1974 are shown in Table A-7.

TABLE A-7

COPPER RANGE COMPANY: METAL STATISTICS

	1970	1971	1972	1973	1974
Finished Copper Production--tons	67,798	58,634	70,427	78,506	66,896
Average Grade of Ore Milled--% Copper	1.077	1.000	1.011	1.002	1.006
Sales of Copper--tons	64,255	61,395	68,218	82.k03	65,947
Average Price Received per Pound of Copper (Net of Freight)[a]	$ .5908	$ .5114	$ .5050	$ .6106	$ .8183
Cost per Pound of Refined Copper Sold[b]	$ .4458	$ .5107	$ .5075	$ .5247	$ .7000
Sales of Silver--Ounces[c]	771,123	590,058	699,160	662,837	737,387
Average Price Received per Ounce of Silver Sold[c]	$1.7698	$1.5660	$1.5927	$2.3408	$4.6937

NOTES: [a] Includes any premium for silver content.

[b] Does not include interest expense and certain unallocated corporate costs not considered material. Includes amounts for overhead and other indirect costs for the periods indicated as follows: 1970--$.0515; 1971--$.0616; 1972--$.0495; 1973--$.0437; 1974--$.0791.

[c] Average price received is net of tolling and outside processing charges. Since this silver is recovered as a by-product, only negligible costs are allocated to it.

SOURCE: Copper Range Company Annual Report.

During 1974, approximately 21 percent of Copper Range's total sales of refined copper were to Revere Copper & Brass Incorporated and approximately 16.5 percent to Anaconda Brass Company ("Anaconda"). During the past ten years these purchasers have accounted for from 21 percent to 27 percent and from 4 percent to 16.5 percent, respectively, of Copper Range's total sales of refined copper. During 1974, 8.7 percent of Copper Range's total sales of refined copper were to the Company's Hussey Metals Division ("Hussey") for use in Hussey's own fabrication activities. During the past ten years, between 8.7 percent and 22.5 percent of Copper Range's total sales of refined copper were to Hussey.

Copper Range's copper is sold primarily on a current basis, with orders generally being accepted only during the month preceding the month of shipment. A contract with Anaconda American Brass Company called for the shipment of 2 million and 2.5 million pounds of copper during each month in 1975, prices to vary with New York Commodity Exchange prices. This contract was subject to cancellation or renegotiation by Anaconda if Copper Range changes its general pricing policy. A second contract called for the monthly shipment to a foreign customer of between 175,000 and 225,000 pounds of copper through April, 1975, at prices based upon copper prices on the London Metal Exchange.

a. Copper Fabrication--Hussey Metals Division

Copper Range has fabricating facilities with an annual capacity of 51.5 million pounds of copper-brass products.

Hussey fabricates a variety of copper and copper-based alloy products including copper bar and strip sold primarily to the electrical industry, standard copper sheet for the construction and metal-working industries and industrial copper strip, plate and sheet sold principally to the electrical, industrial equipment, graphic arts and casket manufacturing industries. It also distributes metal products made by others, including copper, brass and bronze rods and aluminum sheet and strip.

Hussey purchases refined copper in meltable forms (which must be cast before being fabricated) and in rolling shapes from copper producers and from merchants. During the past five years from 1970 through 1974 Hussey purchased from White Pine Copper Company approximately 86 percent, 60 percent, 62 percent, 59 percent, and 26 percent, respectively, of its total copper requirements (excluding copper toll-refined for others). The decline in the percentage of Hussey's requirements purchased from White Pine during 1974 was due, in part, to Hussey's withdrawal from buying, following awards to Hussey of national stockpile copper from February to May.

During the past five years Hussey's sales to Square D Company, a producer of electrical equipment, have constituted from 6.8 percent to 11.2 percent of Hussey's sales of its fabricated products; during the past three years Hussey's sales to General Electric Company have constituted from 5.5 percent to 11.9 percent of sales of its fabricated products. A portion of Hussey's production represents material toll-refined for others. During the period from 1970 through 1974 toll-refined materials represented approximately 3.1 percent, 10 percent, 11.0 percent, 19.6 percent and 19.4 percent, respectively, of Hussey's sales of its fabricated products.

In May 1974, Copper Range adopted a new pricing policy for domestic sales of primary refined copper, which policy is based on New York Commodity Exchange prices. Copper Range believed that this departure from the pricing system used by most other domestic producers offered long-term advantages to it. For a period of approximately four months after the adoption by Copper Range of its new pricing policy, that policy resulted in Copper Range's obtaining significantly higher prices for its copper than would have been obtained under the system previously used; however, during the latter part of 1974, the operation of Copper Range's pricing system resulted in its obtaining prices for its copper significantly below those which it would have obtained under the "producer price" method used by most other domestic producers. During February, 1976, the Company returned to the "producer price" method for the pricing of its refined copper under which prices will be determined and published from time to time based on the Company's evaluation of the market.

With three major fabricators of copper products in the United States, seven medium-size fabricators (including Copper Range) and approximately 70 smaller fabricators, Copper Range's view of the market place is that competition in this area is principally on the basis of price and time of delivery; and that Copper Range's facilities are better suited to the specialized order market for fabricated copper products, which involve somewhat higher production costs and prices, than to the market for larger, standard orders. Copper Range believes that Hussey's network of warehouses provides it with a competitive advantage of terms of delivery at industrial centers.

A 20-year summary of Copper Range's perfromance is shown in Table A-8.

6. Cyprus Mines Corporation

Cyprus Mines Corporation is engaged directly and through its subsidiaries and affiliated companies in the production and marketing of a diverse group of metallic minerals including copper, lead, zinc, iron ore, silver, and molybdenum; ocean transportation or iron ore and other basic commodities; the production, processing and marketing on non-metallic minerals, including premium grade talc, kaolin clays, and cement; and in the manufacture and marketing of wire cable, tubing and related products for the electrical industry.

Cyprus, through Pima Mining and Bagdad Copper, is a source of over 200 million pounds per year of domestically mined copper.

TABLE A-8

COPPER RANGE COMPANY AND SUBSIDIARIES HISTORICAL TABLE--1955-1975

YEAR	Net Income	Number of Common Shares	Income Per Share—Adjusted (1)	Funds Generated From Operations	Capital Expenditures	Cash Dividends Paid	Dividends Per Share—Adjusted (1)	Net Working Capital		Book Value		Non-Current Long-Term Debt	Refined Copper Production (Pounds)
								Total	Per Share-Adjusted (1)	Total	Per Share—Adjusted (1)		
1975	**$(13,692,218)**	**2,343,795**	**$(5.84)**	**$(10,927,930)**	**$10,462,933**	**$ 878,949**	**$ .38**	**$42,965,100**	**$18.33**	**$105,184,232**	**$44.88**	**$31,289,551**	**141,551,410**
1974	17,947,037	2,343,795	7.66	33,427,160	7,519,845	3,515,729	1.50	70,439,438	30.05	119,755,399	51.09	32,666,703	133,795,919
1973	10,568,656	2,343,795	4.51	25,828,218	5,487,854	—	—	48,919,059	20.87	105,324,091	44.94	33,567,779	157,011,226
1972	(6,934,706)	2,343,795	(2.96)	6,041,517	4,116,122	—	—	30,280,555	12.92	94,755,435	40.43	35,019,677	140,853,407
1971	(5,595,703)	2,343,795	(2.39)	4,895,632	11,929,109	585,870	.25	30,267,187	12.92	101,690,141	43.39	36,321,457	117,268,854
1970	9,586,119	2,343,435	4.09	19,412,680	13,953,454	1,116,426	.48	25,680,246	10.97	108,140,577	46.18	24,300,000	135,596,115
1969	15,866,075	2,228,065	6.80	24,797,459	12,137,694	1,060,283	.45	25,062,978	10.74	99,528,978	42.64	27,600,000	156,709,694
1968	9,706,016	2,117,804	4.16	17,554,001	14,416,405	1,028,295	.44	18,018,645	7.73	84,641,250	36.32	33,400,000	147,604,119
1967	614,665	2,054,668	.26	7,971,347	18,074,371	1,025,393	.44	18,664,070	8.03	75,962,056	32.64	35,412,500	101,568,460
1966	8,467,627	2,046,775	3.65	14,503,682	24,611,393	994,231	.43	18,111,475	7.80	76,178,193	32.82	22,400,000	131,069,202
1965	8,532,708	1,982,169	3.69	13,932,806	5,076,296	236,446	.10	29,778,017	12.87	69,351,438	29.96	23,600,000	138,064,322
1964	3,302,035	1,886,625	1.45	8,784,885	3,227,790	—	—	21,525,868	9.48	60,372,823	26.58	24,800,000	118,107,726
1963	3,545,717	1,877,773	1.57	7,229,864	8,721,331	—	—	21,245,272	9.40	57,611,308	25.48	29,642,263	121,998,453
1962	3,299,904	1,877,573	1.46	7,350,579	4,446,070	—	—	25,138,775	11.12	54,906,985	24.28	33,095,731	117,484,025
1961	2,657,639	1,877,473	1.18	6,089,557	3,139,191	—	—	26,470,520	11.71	51,605,514	22.83	36,495,731	112,881,034
1960	(1,291,022)	1,877,473	(.57)	2,329,722	2,932,954	938,761	.42	26,151,143	11.57	48,947,875	21.65	39,080,731	79,583,493
1959	2,405,095	1,877,473	1.06	6,501,502	1,732,632	938,761	.42	31,499,707	13.93	51,177,658	22.64	42,480,731	74,776,464
1958	2,585,309	1,877,473	1.14	6,848,971	883,624	938,749	.42	32,852,309	14.53	49,711,324	21.99	46,861,333	86,431,989
1957	2,164,979	1,877,473	.96	6,442,864	1,968,492	1,876,546	.83	29,081,421	12.86	48,064,764	21.26	51,448,048	74,938,684
1956	9,155,972	1,875,420	4.05	13,137,932	1,885,351	1,787,984	.79	29,110,347	12.89	47,723,992	21.13	51,596,274	80,426,212
1955	9,040,059	1,778,534	4.02	13,221,191	3,673,328	621,419	.28	26,486,265	11.79	40,361,203	17.96	57,850,876	68,137,483

(1) Adjusted to reflect 5% stock dividend 12/15/56;
3% stock dividend 12/9/65;
3% stock dividend 12/9/66;
3% stock dividend 12/6/68;
5% stock dividend 12/5/69;
5% stock dividend 12/4/70

The company operates principally through wholly-owned divisions and corporations in which it has a majority interest and management control. (The two major exceptions are: (1) Marcona Corporation, which is engaged in iron ore mining--principally associated with Peru--and shipping, is owned 50 percent by Cyprus and 50 percent by Utah International as to voting stock and 46 percent each as to equity; (2) Mount Goldsworthy Mining Associates, in which the company owns an undivided one-third interest in the iron ore reserves in Western Australia and participates equally with Consolidated Gold Fields Australia and Utah Development Company in the ownership and management of Goldsworthy Mining Limited, the contract mining company).

The consolidated financial statements include all of the wholly owned and majority-owned subsidiaries of Cyprus Mines Corporation (Cyprus). The majority-owned subsidiaries are the following: Cyprus Anvil Mining Corporation (Cyprus Anvil, 63 percent-owned), Cyprus Pima Mining Company (Cyprus Pima, 50.01 percent-owned), Cyprus Hawaiian Cement Corporation (Cyprus Hawaiian, 92.98 percent-owned), and Cyprus metallurgical Process Corporation (Cymet, 90 percent-owned).

Affiliated corporations which are owned from 25 percent to 50 percent are accounted for by the equity method (wherein Cyprus includes in its investment account for each affiliate the cost of the capital stock acquired, its equity in their retained earnings, and advances made). The revenue, and profits of Cyprus for the last five years are listed in Table A-9.

a. Nonferrous Minerals Group

The company's nonferrous minerals group includes the Pima, Bagdad, and Bruce mines in Arizona; and the Anvil mine in the Yukon Territory of Canada.

Pima Mining Company, which has been managed by Cyprus Mines Corporation since its initial development in the mid-1950's, is a California corporation 50.01 percent owned by Cyprus. It has accounted for most of Cyprus' copper production in recent years. The balance of Pima stock is owned by Union Oil and Utah International, Inc. While essentially a producer of copper in the form of copper concentrates, Pima also recovers minor amounts of molybdenum sulfide concentrates and silver. In 1974, the open-pit copper mine and the concentrator near Tucson, Arizona, produced in concentrates approximately 160 million marketable pounds of copper, approximately one million ounces of silver, plus molybdenite concentrates.

Ore reserves are estimated at approximately one million tons of contained copper.

Copper concentrates are shipped to two Arizona smelters for smelting and refining under long-term contracts. About half of the refined copper and the silver are returned to Pima for sale through normal channels

TABLE A-9

CYPRUS MINES CORPORATION
1971-1975 REVENUES AND PROFITS BY LINES OF BUSINESS

(Dollars in Millions)	1975		1974		1973		1972		1971	
Revenues										
Nonferrous Minerals	$114.1	28%	$132.8	28%	$126.5	32%	$ 96.9	32%	$ 82.9	28%
Inudstrial Minerals	38.5	9	34.6	7	25.4	7	20.0	6	18.0	6
Iron Ore	112.9	28	137.2	29	108.3	28	89.6	30	89.3	31
Shipping	15.7	4	18.3	4	20.3	5	15.3	5	28.3	10
Manufacturing	114.6	29	148.7	31	105.3	27	77.6	26	70.5	24
Other	8.9	2	6.6	1	5.0	1	3.3	1	4.2	1
Subtotal[a]	404.7	100%	478.2	100%	390.8	100%	302.7	100%	293.2	100%
Add minority interests	74.8		86.8		69.7		48.8		42.0	
Total[b]	$479.5		$565.0		$460.5		$351.5		$335.2	
Gross Profit[c] and Other Income										
Nonferrous Minerals	$ 30.0	56%	$ 54.7	59%	$ 44.5	64%	$ 27.3	58%	$ 27.4	54%
Industrial Minerals	4.6	9	5.0	5	3.8	5	3.5	7	2.4	5
Iron Ore	2.1	4	(1.6)	(2)	6.6	9	9.8	21	9.2	18
Shipping	1.6	3	11.0	12	8.1	12	5.4	12	10.4	20
Manufacturing	13.2	25	29.1	31	12.0	17	4.9	11	4.4	8
Other	1.9	3	(4.4)	(5)	(4.7)	(7)	(4.0)	(9)	(2.5)	(5)
Subtotal[a]	53.4	100%	93.8	100%	70.3	100%	46.9	100%	51.3	100%
Add minority interests	14.6		41.6		29.7		15.7		16.9	
Total[b]	$ 68.0		$135.4		$100.0		$ 62.6		$ 68.2	

NOTES: [a] "Revenues" and "Gross profit and other income" are primarily the aggregate of Cyprus' ownership percentage of the revenues or gross profit of each of the various operations or companies in which Cyprus has an interest of 20% or more.

[b] "Total revenues" and "Total gross profit and other income" are the amounts shown in Cyprus' Consolidated Statement of Income, and represent the amounts defined in a above, plus the minority shareholders' interests in the revenues or gross profit of Cyprus' consolidated subsidiaries (owned 50% or more by Cyprus) consisting of Cyprus Anvil, Cyprus Pima, Cyprus Hawaiian Cement, and Cymet.

[c] "Gross profit" represents sales less all costs of production, including depreciation and depletion but before charges for general and administrative costs, interest expenses, and income taxes.

while the balance of the copper and silver is sold to the smelters. Molybdenite concentrates are sold in the open market.

The old Cyprus Island Division and the Bruce Mine Division is not considered a material asset of the company or a foreseeable material contributor to the total revenues of the company, and has essentially been written off.

Cyprus Mines Corporation acquired Bagdad Copper Corporation in June of 1973 in an exchange of stock. Bagdad has sales revenues of about $33 million and earnings of $3.7 million in 1972. Cyprus' financial results are restated to account for Bagdad on a pooling-of-interests basis. Bagdad had production of 18,000 tons of copper in 1974, and about 14,000 tons in 1975. A major expansion of Bagdad is underway, and Cyprus states that its proven ore reserves with nearly 1.5 million tons of contained copper will assure operation at the accelerated rate beginning in 1977, for about 20 years.

b. Financing Operations

Cyprus' principal expansion effort is the major program of the Cyprus Bagdad copper operation in Arizona, budgeted at an estimated cost of $240 million. Completion of the program is scheduled for the end of 1977. At the close of 1975, $55 million had been spent. To finance the first stages of the expansion and other smaller projects, in January 1975, Cyprus sold $100 million of ten-year notes to the public through a group of underwriters. This was the first public borrowing in the Company's history. In May, 1975, a $100 million bank credit agreement was made with a group of seven banks to assure availability of funds in 1976 and 1977 while the Cyprus Bagdad expansion is being completed. No borrowings under the agreement have yet been made. The company is considering alternative financing which would reduce or eliminate the need for bank borrowings.

c. Foreign Investment

On July 25, 1975, the Peruvian Government expropriated the iron ore mining properties and facilities of Marcona Mining Company in Peru. Cyprus' underlying share of the book value of Marcona's investment in the Peruvian properties was approximately $12.9 million which is net of approximately $10.2 million of income taxes previously provided by Cyprus on the undistributed earnings of Marcona. Subsequent to the expropriation, Marcona sustained additional losses which are deemed to be directly associated with the takeover by the Peruvian Government. These losses relate to Marcona-owned and chartered vessels which were involved in transporting ore from the Peruvian mine. Such losses, totaling $5.8 million (Cyprus' share), have been combined with Cyprus' share of the book value of Marcona's investment in the Peruvian properties as losses resulting from the expropriations. Accordingly, Cyprus has written off such losses, totaling approximately $18.7 million as an extraordinary item during 1975.

We understand that United States Government officials working together with Marcona management have held discussions with the Peruvian Government in an attempt to receive just compensation for the expropriated Peruvian assets and to resolve proposed additional tax assessments which have been asserted for prior years. While it is still premature to predict the outcome of these negotiations, any recovery will be recorded as an extraordinary gain when received.

During 1974 hostilities arose on the Island of Cyprus, resulting in the Company's operations being forcibly halted. The Board of Directors on December 11, 1974, therefore directed the write-off of the Cyprus Island Division by the taking of an extraordinary loss in 1974 of the amount of $4.0 million, consisting of net assets of $10.1 million less income tax of $6.1 million.

7. Inspiration Consolidated Copper Company

Inspiration is a domestic company and accounts for about 4 percent of United States refined output. A continuous cast and rolled copper rod-making facility converts about 65 percent of Inspiration's copper production into a fabricated form sold to wire and cable manufacturers.

The bulk of Inspiration's mine production comes from relatively low-cost open-pit operations in Arizona. Total mine production in 1974 was 122 million pounds of copper, of which some 75 percent was obtained from open-pit mining. The Inspiration area mines including heap and dump leaching operations, contributed about 81 percent, Christmas Mine 11 percent, and the Ox Hide Mine's open-pit and heap-leaching operations, 8 percent. At the Christmas Mine, underground mining was plagued by water inflow and unstable rock conditions and operations were suspended in 1966; the open-pit operations have been expanded. The underground operations are being maintained on a standby basis.

Reserves at the Inspiration area are estimated to contain nearly 2 billion pounds of recoverable copper; they have been expanded periodically by inclusion of lower-grade ores as the company becomes able to treat such ores economically.

Approximately 8 percent of Inspiration's output is in the form of electrowon cathode, another 14 percent from waste dump leaching, and another 18 percent from precipitation of cement copper from low-grade solutions. These operations require substantial amounts of sulfuric acid and will be able to utilize that from the new acid plant which came onstream in 1974, in conjunction with the new smelter (discussed below).

In 1972, Inspiration's plan for meeting Arizona smelter emission control standards by 1974 called for a new smelter installation with a capacity of about 300 million pounds of copper per year and costing about $45 million. Some $13.2 million was advanced by a toll customer (Cities Service) to be repaid over the term of a ten-year contract for treating the customer's concentrates. The balance was borrowed on bank revolving credit, to be replaced by long-term debt financing. This smelter complex, involving a new technology, was a substantial undertaking, relative to the size of the company: total net plant and equipment was $66 million at the beginning of 1973 with net working capital of $24 million.

The new smelter came onstream in 1974, at a higher cost than originally estimated, but having the benefit of favorable external financing.

Revenues were $98 million in 1974, and included $83 million in deliveries of copper and $15 million in smelting and refining tolls and fabricated product sales. The average price received for the 112 million pounds of refined copper delivered in 1974 was 74.5 cents per pound. This was 50 percent higher than that received in 1972. Costs before depreciation, depletion, and taxes were about 44 cents a pound in 1974. The company began depreciating its new smelter pollution control facilities in 1974, which increased its average cost by 3 cents/lb. in that year and 4 cents/lb. on the somewhat lower production for 1975; it showed a pre-tax loss in 1975 on deliveries at 63.3 cents/lb., and lower fabricated product sales.

Anaconda has held a significant stock interest in Inspiration, and supported sale of larger block to the Anglo American Group in 1975, the result being that these two groups collectively hold the majority of Inspiration's stock.

Table A-10 presents a 4-year review of Inspiration's operations.

8. Kennecott Copper Corporation

Kennecott together with its subsidiaries is an integrated producer of metals, minerals and metal products, principally copper and copper products. It is the largest domestic producer of copper and an important source of molybdenum, gold, silver, lead, zinc, titanium slag, high purity iron and iron powders. Peabody Coal Company ("Peabody"), which was acquired in 1968, is the largest domestic producer of coal and also the largest supplier of steam coal to the electric utility industry in the United States. Kennecott was required by an order of the Federal Trade Commission to divest itself of its interest in Peabody. This divestiture was completed in 1977.

a. Copper Operations

Kennecott operations four copper properties in the United States. The production statistics are shown in Table A-11. Kennecott's Utah Copper Division mine in Bingham, Utah, is the second largest copper producer in the world, ranking next to Chile's Chuquicamata mine. Most of the blister copper from the Utah smelter is revined at the company's electrolytic refinery at Garfield. (Kennecott's other electrolytic refinery is in Maryland.) Construction continued during 1975 on smelting

TABLE A-10

INSPIRATION CONSOLIDATED: FOUR-YEAR REVIEW

(amounts expressed in thousands, except price and per share figures)

	1975[a,f]	1974[b,f]	1973[c,f]	1972[d]
Deliveries of copper:				
Pounds	87,425	111,568	129,732	145,519
Price per pound[g]	63.34¢	74.50	59.18	50.80
Proceeds	$55,374	83,123	76,774	73,922
Other operating revenue	22,893	14,190	12,605	11,239
Interest and other income	872	1,134	820	388
	79,139	98,447	90,199	85,549
Costs, other than those shown separately below	60,685	62,330	58,878	54,564
Taxes, other than income taxes	6,738	6,768	5,793	5,399
Exploration and metallurgical research	1,941	3,697	2,770	2,241
Selling and general administrative expense	1,920	1,521	1,492	1,227
Interest expense	2,077	3,083	-	-
Depreciation	10,706	9,836	5,800	5,096
Depletion	182	167	221	250
	82,249	87,402	74,954	68,777
Income (loss) before income taxes	(5,110)	11,045	15,245	16,772
Income tax expense (credit)	(1,200)	1,576	644	4,592
Net Income (loss)	$(3,910)	9,469	14,601	12,180
Net income (loss) per share	$(1.37)	3.92	6.05	5.06
Average number of shares outstanding	2,859	2,416	2,414	2,407
Dividends	$4,053	6,283	4,829	4,815
Dividends per share	$1.50	2.60	2.00	2.00
Capital expenditures	$2,789	18,751	40,781	27,746
Stockholders' equity at year end	$114,687	91,208	87,948[e]	77,882[e]
Stockholders' equity per share	$35.07	37.74	36.42[e]	32.35[e]

NOTES:

[a] Demand continues to decline; price drops to 63¢ in January; stockholders approve sale of 850,000 shares of common stock at $37 per share.

[b] Price controls end April 30; price rises to 85¢ by June 5. 40-day strike in 3rd quarter; market weakens with downturn in United States and foreign economies. Price drops to 72¢ by year end.

[c] Increasing worldwide demand. United States prices rise to 60¢ ceiling in 1st quarter. United States government allows increase to 68¢ in December. Pollution control facilities ready for startup at year end.

[d] Copper supply ample; demand modest until year-end upturn. Smelter pollution control facilities and acid plant under construction.

[e] Restated to reflect adjustment related to settlement of excavator-collapse litigation.

[f] See Management's Discussion and Analysis of Summary of Earnings on page 20 of Annual Report 1975.

[g] 1972 and subsequent deliveries are shown at cathode price, whereas 1971 and prior deliveries are on a wirebar basis.

TABLE A-11

KENNECOTT COPPER CORPORATION COPPER STATISTICS

METAL MINING DIVISION PRODUCTION--1966-1975 (UNITED STATES AND CANADA)

Year	Ore Mined, Milled and Treated (000 Net Tons)	Material Removed to Dumps (000 Net Tons)	Copper Produced (Net Tons)	Grade of Ore Mined (Percent Copper)	Molybdenum Produced (000 Pounds)	Gold (Ounces)	Silver (Ounces)
1975	44,158	170,280	288,104	.716	8,833	256,049[a]	4,852,418[a]
1974	62,093	194,676	402,213	.714	10,316	280,561	3,619,922
1973	66,542	179,590	471,721	.766	14,288	342,284	4,246,543
1972	58,493	163,978	460,576	.787	15,041	350,080	4,335,074
1971	59,332	157,689	456,142	.796	18,460	340,636	3,711,141
1970	68,555	179,759	518,888	.773	23,123	404,141	4,338,730
1969	66,698	164,648	495,968	.749	21,471	442,339	3,863,239
1968	47,249	120,154	378,215	.747	17,023	290,495	3,229,258
1967	33,829	69,923	289,016	.778	9,853	214,689	2,769,292
1966	57,921	132,606	454,044	.792	15,577	387,727	4,763,348

COPPER PRODUCTION (BY OPERATING DIVISION) 1975-1974

Divisions	Total Copper Produced from All Sources (Net Tons) 1975	Total Copper Produced from All Sources (Net Tons) 1974	Ore Mined, Milled and Treated (Net Tons) 1975	Ore Mined, Milled and Treated (Net Tons) 1974	Grade of Ore Mined (Percent Copper) 1975	Grade of Ore Mined (Percent Copper) 1974
Chino Mines	53,193	60,557	5,297,820	7,638,638	.855	.861
Nevada Mines	21,393	37,562	4,849,672	7,455,476	.721	.775
Ray Mines	42,036	74,764	6,692,267	11,721,547	1.023	1.043
Utah Copper	171,482	229,330	27,318,000	35,277,300	.613	.652
Total	288,104	402,213	44,157,759	62,092,961	.716	.766

NOTES: [a] The method of reporting production for gold and silver was changed in 1975 from a smelter to a refinery basis in connection with the implementation of a LIFO method of accounting. In the above table refined output of gold and silver is shown for 1975 in contrast to previous years where smelter production of gold and silver is shown. Because of this change in reporting and the lag between the smelting and refining processes, 1975 production of gold and silver was 28,163 ounces and 1,002,912 ounces, respectively.

facilities required to meet sulfur dioxide emission standards. The new facilities are expected to be operational in 1977, and when completed the Magna smelter complex, together with Kennecott's other capacity, is thought to provide the company sufficient smelter capacity for at least the next several years.

The Chino Mines Division comprises the Chino mine at Santa Rita, New Mexico, and a concentrator and smelter at Hurley, New Mexico, nine miles away. The Chino mine is an open-pit operation. The Ray Mines Division operates an open-pit mine at Ray, Arizona, The ore is concentrated and smelted in company facilities at Hayden, Arizona.

The Nevada Mines Division has the smallest copper production. It was shutdown in the third quarter of 1975. Then, the mining and milling operations were curtailed indefinitely in early 1976, because of market conditions.

Development work on a potential copper ore deposit beneath the perimeter of the Utah Copper Division's Bingham Canyon open-pit mine continued during 1975, and development work in this area is scheduled for completion by 1981.

Design engineering continued in connection with future operations of a small copper mine near Ladysmith, Wisconsin. The mine could be in operation by 1978 with estimated annual production of copper in concentrates of 11,000 tons.

Kennecott's subsidiaries include Chase Brass Copper Co. Chase is a leading fabricator of copper and brass mill products; it buys a large portion of its copper from Kennecott, accounting for about 10 percent of Kennecott's copper sales. Profit margins are typically low in this part of the industry; in fact, Chase showed a loss in 1971 and 1972, and 1975.

b. Capital Expenditures and Financing

Capital expenditures for property, plant and equipment by Kennecott (excluding Peabody) increased 39 percent in 1975 to $133.4 million from $95.7 million in 1974. More than half of this amount related to pollution control facilities. Sharply lower internal funds generation resulted in the need for substantial outside financing during the last year. (In a "normal" year, Kennecott could look forward to a cash flow from its copper business equal to roughly its record capital spending in 1975.)

Kennecott's financial capability in the short-run to have funds available for expansion and improvement of its basic copper business, including necessary pollution control expenditures, or for diversification can be very significantly altered by the disposition of its ownership and equity in Peabody Coal operations.

Kennecott increased its long-term debt by $220 million in 1975 by entering into a $200 million term loan agreement with banks, and incurring a $20 million liability for pollution control revenue bonds issued (at 7-3/8 percent interest rate) by the Town of Hurley, New Mexico, for facilities at Chino Mines. It ended the year with $406 million in debt, out of total capitalization of $1,857 million; it reported $262 million in net working capital, up about 10 percent from the previous year. Debt repayment 1976-1980 averages about $41 million per year.

c. Chilean Expropriation Effects

As in the case of Anaconda, analysis of Kennecott's financial picture is complicated (further) by its Chilean holdings and claims: Kennecott's 49 percent interest in Sociedad Minera El Teniente, S.A., a Chilean corporation which owned and operates the El Teniente copper mine in Chile, was expropriated by the Chilean Constitutional Reform Bill, which became effective in July, 1971. In prior years, Kennecott received over $20 million per year in dividends from El Teniente. Kennecott's investment in Chile was carried at $143.3 million at December 31, 1971. $84.6 million of El Teniente Mining Company notes was the subject of a Contract of Guaranty with the United States Overseas Private Investment Corporation. In 1972, Kennecott received a $64.9 million settlement of its expropriation insurance claim, and wrote off (as extraordinary loss) its $50 million ($26 million after tax effects) equity in El Teniente stock.

In 1974, Kennecott and the Chilean Government reached an agreement pertaining to the 1971 expropriation. The aggregate compensation agreed upon, consisting of equity, dividends and interest was $81.4 million less Chilean taxes of $13.4 million. The net amount of $68.0 million consisted of $61.5 million in Chilean notes and the balance, cash.

United States taxes, net of foreign tax credits, amounted to $25.7 million, leaving a net recovery of $42.3 million reported as "extraordinary credit" in 1974. All principal and interest payments due in 1975 were received. Cash flow (amortization) should equal about $6.2 million per year for 10 years, plus interest at 6 percent.

Subordination agreements existing between Kennecott and other lenders, if enforceable, may affect retention by Kennecott of amounts previously received on other notes issued by El Tiente. At December 31, 1975, the amount subject to subordination was approximately $20 million.

d. Sales

Kennecott's sales of metals and metal products were $1,160 million in 1974 and, primarily as a result of a depressed copper market, declined to $769 million in 1975. The average price received in 1975 was 61.2 cents/lb., compared to 76.6 cents/lb. on much larger tonnage in 1974.

Tables A-12 and A-13 show a breakdown of Kennecott's sales and income by principal category, Income is before income taxes, minority interests and extraordinary items. Kennecott's pre-tax operating income from its metals mining and metals product sales (excluding dividends and interest items) was about $233 million in 1974; such operations produced only a few million dollars operating profit (before write-off of a Chase Brass and Copper fabrication plant) in 1975, when Kennecott's copper mining and fabrication businesses were at essentially a break-even level (Kennecott's copper mine production was at about 70 percent of economic capacity).

Kennecott's net earnings before taxes and before equity in net income of Peabody Coal Company, and before minority interests and extraordinary items, was $229 million in 1974 (and a loss of $52 million in 1975); Kennecott made provision for $17 million current and $1 million deferred foreign income taxes, for a total of $56 million before extraordinary items.

9. Newmont Mining

Newmont, a diversified mining investment and operating company, is the parent of Magma Copper Compnay. Newmont also owns, importantly, Carlin Gold Mining Compnay, and 91 percent of Foote Mineral Company, and interests in petroleum and cement companies. Internationally, it has diverse mineral interests, notably in Canadian and African mining companies.

In Canada, the Granduc copper mine in Northern British Columbia is jointly leased with Asarco. The wholly-owned Similkameen project near Princeton, B.C., began producing copper concentrates in mid-1972. Newmont has sold its share of concentrates production at both Canadian properties for several years to Japanese interests.

O'okiep Copper Company, 57.5 percent owned, operates several South African copper mines (Amax has a 17 percent interest). Dawn Mining Company, 51 percent owned, is a medium-size supplier of natural uranium concentrates, from the Midnite Mine. Resurrection Mining Company, a small wholly-owned subsidiary, has a joint venture with Asarco, which is producing lead and zinc concentrates from a mine near Leadville, Colorado; production began early in 1971. Newmont is also engaged in petroleum and natural gas exploration and production in the United States and Canada.

Magma Copper Company is the fourth largest United States copper producer and presently among the more profitable of the major companies (with estimated average total costs of between 50¢ and 60¢/lb.). Its principal copper properties, smelter, and refinery are located at San Manuel, Arizona. Another mine-mill complex is at Superior, Arizona. Magma normally employs about 4,400 persons in copper mining, smelting, and refining operations.

TABLE A-12

KENNECOTT REVENUE ANALYSIS
(in millions of dollars)

Kennecott Revenues	1975	1974
Copper and Copper Products	$506.9	$ 876.3
Molybdenum	20.0	30.1
Gold	40.4	45.8
Silver	14.3	10.0
Lead and Zinc Concentrates	30.7	41.2
Titanium Slag	54.5	50.1
Sorelmetal	78.3	68.8
Iron Powders	10.1	11.4
Other Products	13.4	26.2
Dividends, Interest and Miscellaneous Revenue	15.2	15.5
Sale of 925,000 shares of Kaiser Aluminum & Chemical Corporation common stock	19.4	-
Total	$803.1	$1,175.7
Peabody Coal Company Revenues		
Coal	$705.9	$ 504.1
Dividends, Interest and Miscellaneous Revenue	17.5	10.8
Total	$723.4	$ 514.9

SOURCE: Kennecott's 1975 Annual Report.

TABLE A-13

SALES AND INCOME BY LINE OF BUSINESS, 1972-1974

(in millions of dollars)

	Twelve Months Ended December 31					
	1974		1973		1972	
Kennecott Copper Corporation Business Category	Sales	Income	Sales	Income	Sales	Income
Metals and metal products	$1,160.1	$ 248.7	$1,013.8	$ 236.2	$ 800.9	$ 117.7
Non-operating income[a]		7.3		5.6		9.6
Non-operating deductions		(1.4)		(1.6)		(1.6)
Coal[b]	504.1	23.5	381.3	(3.6)	344.4	10.2
Non-operating income		12.3		18.2		8.3
Non-operating deductions		(6.5)		(7.5)		(2.8)
Shutdown expenses during strikes		(12.8)		(.4)		(4.0)
Other non-operating income		7.9		6.6		2.3
Other non-operating deductions		(28.7)		(29.1)		(32.6)
TOTALS	$1,664.2	$ 250.4	$1,395.1	$ 224.5	$1,145.3	$ 107.1

NOTES: [a] In 1970 a substantial portion of non-operating income resulted from dividends and interest received from Sociedad Minera El Teniente S. A. in which the Company held a 49% equity interest. The Company's interest in El Teniente was expropriated by the Government of Chile during 1971 (see "El Teniente" infra).

[b] Sales and income exclude revenues applied against a reserved production payment.

SOURCE: Form 10-K Annual Report to SEC, 1974

Newmont now has most of its consolidation assets attributable to companies in North America. These companies accounted for 97 percent and 77 percent of consolidated net income in 1975 and 1974, respectively. Total assets are approximately $1.1 billion, of which its investments in companies owned 50 percent of less represent nearly $200 million at cost or equity.

Newmont's total revenues in 1975 were $516.5 million, and net income of $52.9 million, compared to $547.7 million and $113.6 million, respectively, in 1974. Magma Copper Company is the single largest source of Newmont's income: $189.6 million in sales and $20 million in net income for 1975, compared to $251 million and $57 million respectively in 1974.

With respect to financing, Newmont took steps to restructure its corporate debt in 1972. A loan of $50 million from a leading insurance company was closed in November 1972, in the form of 12-year notes, with repayment beginning in December 1978. Simultaneously, the $130 million revolving credit, placed in 1972 with a group of New York banks, was restructured. Magma obtained financing for its air pollution control program in the form of a $30 million pollution control program in the form of a $30 million pollution control revenue bond issue.

Newmont's consolidated long-term debt was 27 percent of total capitalization at December 31, 1975, down from a figure near 30 percent at year-end of 1972.

Table A-14 shows a 3 year financial summary for Newmont.

10. Pennzoil Company (Duval)

Pennzoil engages in oil and gas exploration and production, in processing, refining and marketing of oil and gas and refined petroleum products and in mining and processing copper, molybdenum, potash and sulfur. A five-year financial summary for Pennzoil is presented in Table A-15.

a. Mining

Duval Corporation (Duval), a wholly owned subsidiary of Pennzoil, is engaged in the mining and processing of ores and minerals, principally copper, molybdenum, potash and sulfur. It is the fifth largest copper producer.

Duval owns and operates three open-pit copper-molybdenum mines in Arizona and two open-pit copper mines in Nevada, and four concentrating mills located near its mines. Silver is recovered as a by-product from all the ore bodies, and gold is recovered as a by-product from the Nevada ore bodies. Duval's largest mine, the Sierrita Property located near Tucson, Arizona, is owned by Duval Sierrita Corporation (Duval Sierrita), a wholly owned subsidiary of Duval.

TABLE A-14

NEWMONT MINING CORPORATION AND SUBSIDIARIES
THREE-YEAR SUMMARY

	1975	1974	1973
Gross Income			
Sales and other operating revenue	$516,524,000	$547,738,000	$427,780,000
Dividends, interest and other income	14,367,000	16,043,000	11,894,000
Equity in income of affiliated companies	12,210,000	40,304,000	38,949,000
Net gain on security transactions (on an identified cost basis)	13,547,000	740,000	3,400,000
	556,648,000	604,825,000	482,023,000
Costs and Expenses			
Operating costs and expenses	414,995,000	366,473,000	276,774,000
Depreciation and depletion	32,342,000	26,098,000	20,056,000
Granduc write-off	-	12,278,000	-
Exploration and research	11,237,000	15,007,000	15,910,000
Interest expense	20,237,000	17,619,000	18,825,000
Income taxes (current and deferred)	22,197,000	45,227,000	40,072,000
Minority interest	2,752,000	8,517,000	7,010,000
	503,760,000	491,219,000	378,647,000
Income before extraordinary items	52,888,000	113,606,000	103,376,000
Extraordinary items	-	-	-
Net Income	52,888,000	113,606,000	103,376,000
Preferred stock dividends	2,578,000	2,833,000	3,181,000
Net Income Applicable to common stock	$ 50,310,000	$110,773,000	$100,195,000
Cash Dividends Paid on Common Stock	$ 39,356,000	$ 37,858,000	$ 27,289,000
Average Share of Common Stock Outstanding	24,580,000	24,332,000	24,135,000
Per Share of Common Stock Based on the average number of shares outstanding and after preferred stock dividend requirements			
Income before extraordinary items	$2.05	$4.55	$4.15
Extraordinary items	-	-	-
Net income	$2.05	$4.55	$4.15
After full conversion of convertible preferred stock (amount before extraordinary item in 1972 is $1.84)	$2.00	$4.33	$3.92
Cash dividends	$1.60	$1.55	$1.13
Stock dividends	-	-	-
Expenditures for Property, Plant and Mine Development	$ 53,231,000	$ 55,769,000	$ 47,636,000
Stockholders' Equity	$648,331,000	$637,370,000	$564,361,000

TABLE A-15

STATISTICS FOR PENNZOIL COMPANY AND SUBSIDIARIES

	1975	1974	1973	1972	1971
Gross Revenues--In Thousands[a]					
Oil and Gas Production[b]	$ 313,168	243,890	135,463	103,073	94,821
Refining and Marketing	518,097	441,796	282,765	196,603	146,931
Mining	284,308	281,425	201,723	166,356	130,504
Gross Operating Income--In Thousands[a,c]					
Oil and Gas Production[b]	$ 164,947	121,904	45,833	38,417	33,999
Refining and Marketing	24,310	27,202	31,617	23,358	20,272
Mining	36,890	70,240	33,989	15,987	15,896
Net Crude Oil and Plant Products Produced (Bbls.)[b]	21,143,908	19,821,548	16,983,435	15,548,091	14,937,768
Daily Average	57,929	54,305	46,530	42,481	40,925
Net Natural Gas Produced (Mcf.)[b]	270,315,000	273,360,000	246,435,000	221,396,000	214,800,000
Daily Average	741,000	748,000	675,000	605,000	588,000
Crude Oil and Liquids Processed (Bbls.)	18,529,083	17,388,496	13,283,971	12,114,159	11,640,078
Daily Average	50,765	47,640	36,394	33,099	31,891
Refined Products Produced (Bbls.)					
Lubricating Oils, Waxes and Other	10,993,976	10,492,515	6,356,766	5,307,107	5,135,694
Gasoline and Naphtha	6,885,384	6,361,269	6,257,666	5,981,568	5,884,236
Mined Product Sales--In Thousands					
Sulphur--Long Tons	1,787	1,993	1,762	1,400	1,026
Potash--Short Tons	1,043	1,527	1,357	1,109	1,270
Copper--Pounds	313,217	244,889	251,032	282,229	193,216
Molybdenum--Pounds	16,371	20,924	21,965	16,596	10,405
Silver--Ounces	1,805	1,287	1,570	1,621	1,348
Gold--Ounces	19	10	8	13	16
Number of Employees	9,433	9,487	8,872	7,726	7,689
Payroll and Payments for Account of Employees--In Millions	$ 146.1	122.8	102.9	84.2	77.2

NOTES: [a] Without adjustment for certain intercompany transactions.

[b] Includes POGO's entire interest but does not include any amounts attributable to PLATO.

[c] Income before interest charges, Federal income tax and outside shareholders' interest.

SOURCE: Pennzoil Annual Report.

Duval's copper concentrates and precipitates are currently sold as such or are toll smelted and refined by others for redelivery to and marketing by Duval. Duval has recently completed the physical construction of and is now in the process of starting up the operating of a CLEAR-process hydrometallurgical plant near the Sierrita Property for the electrolytic production of copper crystals (equivalent to a high-grade blister copper) from concentrates produced at the Esperanza and Sierrita Properties and precipitates produced at the Esperanza and Mineral Park Properties. The patented CLEAR process is designed to create no solid, liquid or gaseous pollution. The plant is intended to produce 40,000 tons of copper crystals per year. It was estimated that the plant will cost a total of $43 million, including capitalized interest and start-up and test costs. The copper crystals will be marketed as such to refiners and others or will be toll-refined by others for marketing by Duval.

Most of Duval's molybdenum concentrates are currently treated by Duval for marketing as molybdenum sulfide or for roasting in Duval's roasters. The roasted product, molybdenum trioxide, is packaged and marketed by Duval as technical molybdic oxide. The balance of the molybdenum concentrates is converted into ferro-molybdenum, one of a broad line of products offered to the steel and foundry industries. In the last several years, Duval has accounted for about 18 percent of domestic molybdenum production (Amax accounts for about 60 percent, Kennecott and Molycorp most of the balance).

b. Duval Sierrita--GSA Contract

In November, 1967, the United States General Service Administration (GSA) and Duval Sierrita Corporation entered into a domestic copper production expansion contract pursuant to the provisions of the Defense Production Act of 1950 for the development of the low-grade copper-molybdenum Sierrita orebody adjacent to Duval's Esperanza Property. Construction of facilities were substantially completed in March, 1970. Approximately $181 million was required to develop the original project (not including the cost of the expansion project referred to below) of which $83 million was obtained from the GSA in the form of advances against future deliveries of copper produced from the property; $48.75 million from commercial bank loans guaranteed in part by the GSA; $10 million from Pennzoil; and the remainder from Duval in equity or loans. Duval provided management and technical guidance to Duval Sierrita at cost.

The contract with the GSA provided that repayment of advances would be made by delivery of about 218.4 million pounds of copper to the GSA prior to June 30, 1975. The advances were credited at the rate of 38¢ for each pound of refined copper delivered. While the contract provided that certain minimum deliveries must be made at stated intervals Duval Sierrita was entitled to sell in the open market its molybdenum and by-product silver production and such amount of its copper production as may be necessary to cover all cast operating expenses and maintain working capital.

In May, 1970, these contracts were amended to provide for an increase in the mine and mill capacity at the Sierrita Property. Duval Sierrita agreed to spend not less than $8 million on additional facilities and guaranteed the GSA an average rate of ore throughput on an annual basis of not less than 72,000 tons per day. In turn, the GSA and the commercial banks agreed to permit Duval Sierrita to sell on the open market for its own account 90 percent of production attributable to any ore throughput exceeding 72,000 tons per day. The remaining 10 percent of such production (net of sales required to meet cash operating expenses attributable thereto) was to be delivered to the GSA at a fixed price of 38¢ per pound.

The facilities for integrated copper-molybdenum milling operations were completed in the latter part of 1970 and normal production commenced subsequently.

Generally, prices and costs for copper in the United States subsequently rose substantially in the inflationary period of 1970-1974. In 1975, Duval Sierrita arranged a substantial acceleration of deliveries to the GSA, after obtaining a new $55 million bank credit, and by December 1975, the total amount of copper required to be delivered to the GSA had been made available for delivery to the GSA at refineries. Duval Sierrita's cash flow in excess of that needed to cover cash operating expenses and capital additions and replacements and to maintain working capital is now dedicated to accelerate the repayment of the bank loans, and Duval Sierrita's operations will not contribute to Duval's cash flow until the bank loans have been repaid.

Duval estimates the proven ore reserves of the Sierrita Property to be 523 million tons with an average copper content of 0.33 percent and an average molybdenum content of 0.032 percent.

c. Marketing

Duval produced 132,148, 132,594 and 137,956 tons of copper in 1973, 1974, and 1975, respectively. This production accounted for approximately 8 percent of domestic mine copper production in 1973 and 1974 and approximately 10 percent of such production in 1975. In 1975 Duval sold 156,604 tons of copper by the acceleration of deliveries (65,000 tons) to discharge Duval Sierrita's obligations under the GSA contract. Substantially all copper sales during this period were made in the United States.

Asarco currently smelts and refines substantially all Duval's copper concentrates and precipitates. Under existing arrangements Asarco purchases a portion of the copper production (in the form of copper concentrates and precipitates) and smelts and refines the balance on a toll basis for redelivery to and marketing by Duval. Duval's current sales are made to a number of wire and brass mills.

Through 1975, Duval's sales of refined copper on the open market were priced on the basis of the Metals Week wirebar average for United States producers, delivered. Effective January 1, 1976, Duval declared its own pricing basis.

d. Revenues

Metals sales constitute the bulk of Duval's revenues and typically the major part of gross operating income. Mining revenues were approximately $280 million in both 1974 and 1975; mining operations income was approximately $47 million in 1975, compared to $70 million in 1974, when it represented about one-third of Pennzoil operating income.

During the past eight years (since the acquisition of Duval by Pennzoil through merger with the United Gas Corporation), Duval has spend more than $419 million for the acquisition and development of new properties and the installation of new facilities, including more than $49 million in 1975. The new facilities require Duval to market substantially increased amounts of its products and to participate in markets, both domestic and foreign, in which it did not previously participate to a significant extent.

11. Phelps Dodge Corporation

Phelps Dodge (PD) is the second largest domestic copper producer. It sells part of its copper production as refinery shapes or as rods, and fabricates the remainder of its copper (as well as copper purchases from others) for sale as wire, cable, and tubular products. PD also does smelting and refining of copper and rolling of copper rod on tool for others. Approximately one half of its refinery production in 1974 and 1975 was material under contract for other companies.

PD participates in the uranium market through Western Nuclear, full ownership of which was acquired in 1971, and is expanding this subsidiary's uranium mining and milling production capacity.

PD investments include, a 40 percent equity in Conalco, Inc., a large domestic aluminum producer and fabricator; a 16 percent interest in Southern Peru Copper; plus various interests in 25 companies in 19 countries abroad manufacturing wire and cable and related products.

Table A-16 is a ten year summary of Phelps Dodge operations.

a. Mining

Phelps Dodge produces copper from open-pit copper mines at Morenci, Ajo, Metcalf, Arizona; and Tyrone, New Mexico. All the ore at Phelps Dodge's mines is now sulfide ore. As of early 1973, Phelps Dodge estimated the copper ore reserves at its properties at approximately 1,580 billion tons of ore, containing 9.4 million tons (18.8 billion pounds) of recoverable copper. The Morenci property, the largest of

TABLE A-16

PHELPS DODGE: TEN-YEAR SUMMARY OF OPERATIONS (1966-1975)

(dollar amounts are in millions except per share figures and copper price)

	1975	1974[a]	1973	1972	1971[a]	1970	1969	1968[a]	1967[a]	1966
Phelps Dodge-mined Metals:										
Copper--thousand tons	249.7	281.3	315.6	305.4	281.2	313.5	284.2	213.2	156.7	271.7
Silver--thousand ounces	1,806	2,212	2,564	2,385	2,425	2,647	2,425	1,780	1,203	2,126
Gold--thousand ounces	41	52	68	70	70	82	84	71	48	87
Copper sales--thousand tons	276.6	231.7	324.7	327.7	288.8	270.9	283.5	212.4	157.2	272.3
Copper price--cents per pound[b]	64.2	77.3	59.5	51.2	52.0	58.2	47.9	42.3	38.6	36.6
Revenues and Expenses:										
Operation revenues	$ 780.8	1,026.1	962.0	765.8	703.6	716.2	628.9	531.7	509.8	554.0
Non-operating revenues	27.4	14.3	21.2	14.7	15.3	17.9	21.1	16.7	17.5	15.5
Costs and expenses exclusive of items shown below	636.5	789.0	705.3	554.1	524.1	495.7	464.3	412.5	415.3	395.9
Exploration and research	23.0	18.0	14.9	11.9	11.2	8.2	5.5	4.3	3.6	3.1
Selling and general administrative expenses	31.9	34.1	32.6	31.0	27.8	27.7	24.3	19.1	19.4	18.3
Depreciation, depletion and amortization	35.1	36.6	35.9	34.2	29.1	21.9	19.5	15.0	11.9	13.5
Interest expense	37.4	24.4	15.8	14.1	8.7	6.6	4.6	2.5	0.6	-
Income taxes	(13.2)	36.7	66.7	44.8	39.9	65.1	43.3	31.3	25.6	56.5
Equity earnings (losses) less income tax	(11.1)	10.9	(3.0)	(8.2)	(4.3)	(0.9)	1.0	0.9	-	-
Extraordinary items less income tax	-	9.2	-	-	2.0	4.8	-	-	-	-
Net Income	$ 46.4	121.7	109.0	82.2	75.8	112.8	89.5	64.6	50.9	82.2
Dividends	$ 45.2	45.2	44.6	43.1	42.9	42.3	39.3	35.3	34.4	43.1[c]
Capital Outlays:										
Capital expenditures	$ 203.2	274.7	178.0	94.2	75.5	89.2	84.7	73.9	55.0	30.9
Pre-operating mine development	19.6	14.4	10.3	11.4	8.1	4.6	9.4	8.3	3.2	0.4
Investments	2.8	7.3	5.9	1.6	6.6	0.3	7.7	5.7	5.1	-
Per Share										
Net income[d]	$ 2.26	5.92	5.31	4.01	3.72	5.60	4.43	3.20	2.52	4.05
Dividends	2.20	2.20	2.175	2.10	2.10	2.10	1.95	1.75	1.70	2.125[c]
Stock prices (NYSE)--high	40.25	49.88	50.25	44.50	48.00	56.50	52.50	55.75	40.00	41.50
--low	29.00	25.50	38.75	34.38	28.00	34.00	39.13	29.75	31.25	27.13
Average number of shares outstanding (in thousands)	20,563	20,567	20,526	20,514	20,379	20,153	20,179	20,178	20,222	20,285
At December 31										
Net current assets	$ 146.5	92.7	217.0	213.7	208.5	141.8	137.3	126.6	173.6	215.2
Total assets	1,652.1	1,492.9	1,268.9	1,043.1	988.7	878.5	792.3	652.8	610.1	581.7
Long-term debt	522.5	327.1	281.9	181.3	166.0	86.1	77.2	28.5	2.7	-
Shareholders' equity per share	43.44	43.38	39.67	36.53	34.62	32.90	29.43	26.95	25.25	24.65

NOTES:
[a] Primary metal production curtailed by strikes.
[b] Metals Week average domestic delivered price--wirebars.
[c] Includes extra of 42-1/2¢ per share.
[d] Based on average number of shares outstanding for year.

SOURCE: Phelps Dodge Annual Report.

PD's mines, also holds about 60 percent of PD's reserves. Additional properties are undergoing exploration and development.

PD produced a record 319.6 thousand tons mine output of copper in 1973; production was lower in 1974 due to strikes and in 1975, due to reduced demand. Additional capacity has recently been brought in at the Metcalf mine, at a cost of $194 million to replace the Bisbee operations and to raise overall capacity to 330,000 tons per year. The Tyrone mine was expanded in 1972-1973 to 100,000 tons annual production capacity.

In general, Phelps Dodge is thought to be one of the lowest cost copper producers. The company has reported that production costs per pound of copper are lowest at Morenci, which mines the largest quantity of ore.

b. Copper Smelting

Phelps Dodge's copper smelters are located at Morenci, Ajo, and Douglas, Arizona; and the new Hidalgo smelter in New Mexico. In 1975, production of the Morenci mine and most of that from Tyrone was treated at the Morenci smelter, which has the capacity to treat nearly 1 million tons annually of copper-bearing materials such as concentrates, ore and scrap. Production of the Ajo mint, and a portion of the Tyrone production, was treated at the Ajo smelter, which has the capacity to treat approximately 300,000 tons of new metal-bearing material annually. Production from a portion of Tyrone, as well as custom material and scrap, was treated at the Douglas smelter, which has capacity to treat approximately 860,000 tons of new metal-bearing material annually. The smelters produce anode copper--copper which is then shipped to Phelps Dodge refineries for refining. The new Hidalgo smelter, was expected to begin treating concentrates from Tyrone in the second quarter of 1976. The smelter is the first in the United States to use the flash process developed in Finland.

c. Other Facilities

Refinery capacity is located at El Paso (electrolytic and fire-refined) and Laurel Hill, New York (80,000 tons electrolytic and 20,000 tons fire-refined). Wire mills are located in New York (4), New Jersey (2), Indiana (2), Kentucky and Arkansas. Tube mills are in California and New Jersey. A brass foundry is operated in Alabama and interests are held in 13 foreign fabricating operations.

The company has approximately 14,000 total employees, some 50 percent of whom are associated with primary copper production.

Sales and operating revenues in 1974 exceeded $1 billion, of which approximately 35 percent was attributable to deliveries from PD's own mine production. Net income after taxes was $112.5 million. Both sales and net income were down substantially in 1975, due to decline in nonferrous metals demand and prices.

In 1975 capital expenditures and pre-operating developments at mines, concentrators, and smelters totaled about $200 million, compared with about $260 million in 1974. Of the 1975 expenditures, $39.0 million was spent at Morenci (56.3 million in 1974), $13.0 million at Metcalf ($64.0 in 1974), $3.4 million at Ajo ($5.9 million in 1974), $2.4 million at Tyrone ($2.6 million in 1974), $6.1 million at the Douglas smelter ($13.7 million in 1974), and $93 million at the Hidalgo smelter.

This accounts for the bulk of all Phelps Dodge expenditures, the balance of the order of $20 million per year or so going into the manufacturing (fabricating) plants and affiliates.

In 1975, a total of $15.3 million was expanded for air quality control facilities at the Morenci, Ajo, and Douglas smelters ($45.2 million in 1974), and $21.5 million for the related tailings leach programs at Morenci ($21.6 million in 1974).

Capital investment in the Hidalgo smelter project was $226.6 million by the end of 1975, of which $92.9 million was spent during the year. Total investment, including the new town of Playas and the 36-mile industrial railroad linking the smelter with the Southern Pacific system, is expected to amount to about $240 million.

Phelps Dodge has agreed with Cyprus Mines Corporation to treat at Hidalgo, beginning in 1978, concentrates from Cyprus' expanded Bagdad, Arizona mine. Additional facilities to make this possible, including a second sulfuric acid plant, are being designed and construction is expected to begin in the second quarter of 1976. Under this agreement, Cyprus will lend PD $35 million toward the cost, estimated at $40 million, of the additional facilities.

Phelps Dodge had $166 million in long-term debt outstanding at December 31, 1971. Reports to the Securities and Exchange Commission showed that, as of September 30, 1973, long-term debt had increased to $288 million primarily as a result of the issuance of nearly $100 million primarily as a result of the issuance of nearly $100 million in Pollution Control obligations. Additional long-term debt and pollution control financing were obtained subsequently; by year-end of 1975, long-term debt was 31 percent of total capitalization, the highest among the traditional copper companies (i.e., excluding the oil companies from the comparison).

APPENDIX A

NOTES

1. Anaconda is now a part of Atlantic Richfield.
2. In 1975, Anaconda acquired the Walworth Company, one of the leading valve manufacturers.

APPENDIX B

LONG-RUN SUBSTITUTION FOR COPPER

This appendix presents detailed information on trends in long-run substitution for copper in markets.

A. CONDUCTOR APPLICATIONS

Aluminum has made significant inroads into copper markets in certain electrical conductor applications, specifically in busbar and switchgear, building wire, communication cable, and power cable. To a lesser degree, aluminum has been substitute, on occasion, for copper in motor and motor control parts and in automotive electrical apparatus and consumer electronics goods.

In the building wire industry, substitution of aluminum for copper has been increasing rapidly since 1964. The amount of substitution is directly related to the conductor size: the larger the conductor, the greater the percentage of aluminum building wire.

Substitution of aluminum for copper in the small building wire sizes is minor because little monetary savings per unit length can be realized in these sizes. In addition, mechanical connectors of aluminum to aluminum or aluminum to copper are a problem, particularly in the smaller wire sizes. Training of electricians on how to make proper connections when installing aluminum building wires has not always been done, and the resultant troubles have caused many building contractors to abstain from the use of aluminum conductor building wire in small sizes.

The use of aluminum conductors in the communications industry is minimal at present. However, there is much research activity in this field by both manufacturers and end users because large savings in communication conductor costs are indicated if a number of technical problems can be solved.

The substitution of aluminum for copper in the power-cable field has progressed expeditiously and, in recent years, approximately 40 percent of the insulated power cables and almost 100 percent of the bare conductors have been aluminum. Aluminum has such a weight advantage over copper that aluminum-conductor, steel-reinforced cable has been used for most long-transmission lines for more than a decade. Recently introduced aluminum alloys are being used as conductors on overhead transmission lines.

Copper remains the first choice for automotive wiring at current prices. In areas where space in an existing design is not a problem, the use of the larger sizes of aluminum wire will increase. Examples of such applications are battery cables, air conditioners, clutch coils, alternators, anti-skid devices, horn coils, and some accessory motors.

Copper and aluminum are used widely as electronic consumer items (TV receiver, radios, record players, tape recorders, etc.). For many years the normal electrical conductor in consumer items was an insulated copper wire. However, with the advent of solid-state electronics, a large increase in aluminum usage occurred because of its excellent heat-sink capabilities. With the increasing usage of printed circuits or wiring boards of epoxy glass and epoxy coated steel, and of thin and thick film ceramic units, nickel, gold, silver, tantalum, and rhodium, as well as aluminum have begun competing with copper for this application.

B. HEAT-EXCHANGER APPLICATIONS

Substitution of aluminum for copper in radiators is possible given the fabrication techniques and the available supply of metal in the required sheet and strip forms. Automotive radiators have been built of aluminum in limited quantities and are similar in appearance and heat-transfer characteristics to copper radiators.

All but a small proportion of the motor vehicles currently in service use radiators constructed of copper and copper alloys. Copper has been traditional for this application because of its heat transfer properties, corrosion-resistance, ease of fabrication, and ease of joining the various components by conventional "soft" soldering techniques.

Experience has shown that copper radiators are quickly and economically repairable with the use of minimal additional copper. Present repair techniques for aluminum radiators are either unreliable or available only at great expense at a limited number of shops. Most aluminum radiators today are replaced when leaks occur.

The major deterrent to volume production of aluminum radiators seems to be high capital equipment costs plus the unamortized cost of equipment presently used for production of copper radiators. Total cost of industry conversion has been estimated to be more than $200 million.

Currently, more than 90 percent of the primary surfaces in automotive air-conditioner evaporators and condensers are aluminum, and domestic refrigerators and freezers have used all-aluminum evaporators and steel condensers for years. Copper and aluminum are completely substitutable in this area.

Copper tubing is still the predominant primary surface in heat exchangers for commercial refrigerators and freezers, and room, central residential, and commercial air conditioners. Aluminum tubing is used in less than 10 percent of these products. Extensive manufacturing development is necessary before aluminum could be considered completely substitutable for copper in these applications.

Aluminum-alloy tubing in air conditioners has up to twice the wall thickness of copper, but still maintains a weight and cost advantage.

Production processes for most aluminum tube commercial and residential air conditioners and commercial refrigerator and freezer heat exchangers are similar to those for copper tube heat exchangers with the exception of joining or assembly methods. The cost of converting an assembly line for copper-tube heat exchangers to aluminum is relatively low because most of the production equipment could be used with either metal, but not simultaneously.

Additional field experience is required before aluminum will be substituted widely for copper in room-air-conditioner condensers and commercial heat exchangers using water as a secondary refrigerant or as a heating medium. These products account for approximately 25 percent of the total tubing requirements and pose specific corrosion problems to aluminum. Codes now limit the use of aluminum-tube heat exchangers mounted in ducts. However, these codes are being re-evaluated and soldered aluminum-tube heat exchangers may be accepted in the near future.

Aluminum has been tried in five different U. S. power plants. In two cases, failure occurred in about a year; in another instance, failure occurred in five years; and in the other two, condenser tubes lasted ten years. Fresh water was used for cooling in all cases.

There are problems, seemingly insurmountable, that must be overcome to use aluminum in the main condenser of power generating stations. The necessary volume of circulating or cooling water is very great and its quality is extremely variable. To insure against attack of aluminum tubing by water, controls and conditioning equipment not customarily used in electrical generating stations would be required.

Applications Requiring Corrosion Resistance

Copper and aluminum compete directly in many conductivity and heat-exchanger applications, and in some structural applications, but rarely in applications in which corrosion resistance is the prime requisite.

In many applications, copper and aluminum are not mutually substitutable. Even where an overlap exists (valves and fittings, for example), a serious decline in copper usage has not occurred.

C. ELECTROPLATING AND COATINGS

Copper has been, and will continue to be, widely used in coatings applied by electroplating and in forms made by electrodeposition. Aluminum coatings by electroplating are not easily applied and currently are in negligible use. In coating applications, copper and aluminum are not interchangeable because the electro-deposition of aluminum requires highly special procedures. In recent years, electrodeposited coatings of aluminum would have cost 6 to 10 times those of copper, technical difficulties would require major changes in equipment.

Recent developments in the thermal decomposition of liquid and vapor phase aluminum organometallic compounds may, however, permit the use of aluminum in coatings for steel and in protective paints in the future.

D. ALLOYING APPLICATIONS AND COATINGS

Copper is essential in all U. S. coins because of the requirements of the large automatic vending machine industry. These machines are designed to accept coins with the properties of coin silver. To match these properties, silver-free coins must contain a high percentage of copper.

Aluminum is not used in any U. S. coins. It is too light in weight to operate coin-operated machines and has less wear resistance than currently used metals in coins. Thus, aluminum is an unlikely candidate for use in this field in the foreseeable future.

E. ORDNANCE AND ACCESSORIES

Although other materials have been employed for certain fuse components, copper alloys continue to be the major ingredient. Periods of critical shortage in copper supplies have prompted efforts to substitute other materials in fuses for several years. Efforts to replace copper with aluminum also have been related to reducing weight.

In recent years, more than 30 different fuses have been used by the U. S. Army. Among standard models, the number of copper and/or aluminum components varies from practically none to a significant proportion. In some, the original functioning requirements were such that other materials (such as steel) were satisfactory for almost all components. In others, aluminum alloys have replaced copper alloys to a certain extent as the result of a gradual substitution program. In still others, especially the recent models developed for entirely new projectiles, aluminum alloys comprise a comparatively large proportion of the materials used. Thus, a part-by-part analysis of the degree to which copper alloys have been or may be replaced by aluminum alloys becomes impractical.

For the manufacture of cartridge cases, no commercially available aluminum alloy has proven ideal enough to seriously threaten the use of copper.

APPENDIX C

INTERINDUSTRY RELATIONSHIPS OF PRIMARY COPPER, COPPER ROLLING AND DRAWING, UNITED STATES, 1967

INTERINDUSTRY RELATIONSHIPS OF PRIMARY COPPER, UNITED STATES, 1967

From	To	Description	($ millions)
38.01	27.01	Industrial Inorganic and Organic Chemicals	12.3
38.01	37.01	Blast Furnaces and Basic Steel Furnaces	25.8
38.01	37.02	Iron and Steel Foundries	6.7
38.01	37.04	Primary Metal Products, n.e.c.	22.8
38.01	38.01	Primary Copper	823.8
38.01	38.02	Primary Lead	.4
38.01	38.03	Primary Zinc	3.8
38.01	38.04	Primary Aluminum	8.5
38.01	38.05	Primary Nonferrous Metals, n.e.c.	67.6
38.01	38.06	Secondary Nonferrous Metals	23.6
38.01	38.07	Copper Rolling and Drawing	871.7
38.01	38.08	Aluminum Rolling and Drawing	23.8
38.01	38.09	Nonferrous Rolling and Drawing, n.e.c.	13.8
38.01	38.10	Nonferrous, Wire Drawing and Insulating	426.5
38.01	38.11	Aluminum Castings	9.8
38.01	38.12	Brass, Bronze, and Copper Castings	89.2
38.01	38.13	Nonferrous Castings, n.e.c.	2.5
38.01	40.02	Plumbing Fittings and Brass Goods	17.9
38.01	42.03	Heating Equipment, except Electric	8.5
38.01	42.08	Architectural Metal Work	40.7
38.01	48.05	Printing Trades Machinery	4.4
38.01	48.06	Special Industry Machinery, n.e.c.	4.7
38.01	49.01	Pumps and Compressors	5.9
38.01	49.05	Power Transmission Equipment	6.8
38.01	53.04	Motors and Generators	8.8

INTERINDUSTRY RELATIONSHIPS OF PRIMARY COPPER, UNITED STATES, 1967

(Continued)

From	To	Description	($ millions)
38.01	53.05	Industrial Controls	6.1
38.01	68.01	Electric Utilities	1.2
38.01	71.02	Real Estate	1.5
38.01	83.00	Scrap, Used and Secondhand Goods	1.5
38.01	88.00	Total Intermediate Output	2,547.8
38.01	93.00	Net Inventory Change	14.1
38.01	94.00	Net Exports	171.8
38.01	97.10	Federal Government Purchases, Defense	-106.3
38.01	97.20	Federal Government Purchases, Others	18.8
38.01	99.02	Total Final Demand	98.3
38.01	99.03	Total Output	2,646.1
38.01	99.04	Transfers-Out	83.9

INTERINDUSTRY RELATIONSHIPS OF COPPER ROLLING AND DRAWING, UNITED STATES, 1967

From	To	Description	($ millions)
38.07	9.00	Stone and Clay Mining and Quarrying	.8
38.07	11.01	New Construction, Residential Buildings (Nonfarm)	138.4
38.07	11.02	New Construction, Nonresidential Buildings	87.8
38.07	11.03	New Construction, Public Utilities	17.7
38.07	11.05	New Construction, All Other	7.6
38.07	12.01	Maintenance and Repair Construction, Residential Buildings (Nonfarm)	34.2
38.07	12.02	Maintenance and Repair Construction, All Other	23.9
38.07	13.01	Complete Guided Missiles	.2
38.07	13.02	Ammunition, Except for Small Arms, n.e.c.	6.2
38.07	13.03	Tanks and Tank Components	.3
38.07	13.05	Small Arms	.5
38.07	13.06	Small Arms Ammunition	100.4
38.07	13.07	Other Ordnance and Accessories	.6
38.07	17.06	Coated Fabrics, Not Rubberized	.3
38.07	20.01	Logging Camps and Logging Contractors	.5
38.07	27.01	Industrial Inorganic and Organic Chemicals	.2
38.07	27.04	Miscellaneous Chemical Products	2.7
38.07	32.04	Miscellaneous Plastics Products	.3
38.07	36.02	Brick and Structural Clay Tile	.1
38.07	37.01	Blast Furnaces and Basic Steel Products	6.0
38.07	38.01	Primary Copper	45.3
38.07	38.04	Primary Aluminum	.7
38.07	38.07	Copper Rolling and Drawing	77.1
38.07	38.08	Aluminum Rolling and Drawing	82.5
38.07	38.09	Nonferrous Rolling and Drawing, n.e.c.	13.3
38.07	38.10	Nonferrous Wire Drawing and Insulating	579.9
38.07	38.12	Brass, Bronze, and Copper Castings	11.5

INTERINDUSTRY RELATIONSHIPS OF COPPER ROLLING AND DRAWING, UNITED STATES, 1967

(Continued)

From	To	Description	($ millions)
38.07	38.14	Nonferrous Forgings	24.9
38.07	40.01	Metal Sanitary Ware	1.8
38.07	40.02	Plumbing Fittings and Brass Goods	50.2
38.07	40.03	Heating Equipment, Except Electric	24.1
38.07	40.04	Fabricated Structural Steel	2.3
38.07	40.05	Metal Doors Sash and Trim	1.5
38.07	40.06	Fabricated Plate Work (Boiler Shops)	26.7
38.07	40.07	Sheet Metal Work	8.1
38.07	40.08	Architectural Metal Work	4.8
38.07	40.09	Miscellaneous Metal Work	2.7
38.07	41.01	Screw Machine Products and Bolts, Nuts, Rivets, and Washers	93.9
38.07	41.02	Metal Stampings	68.4
38.07	42.01	Cutlery	1.3
38.07	42.02	Hand and Edge Tools Including Saws	3.5
38.07	42.03	Hardware, n.e.c.	35.9
38.07	42.05	Miscellaneous Fabricated Wire Products	14.1
38.07	42.08	Pipe, Valves, and Pipe Fittings	98.1
38.07	42.11	Fabricated Metal Products, n.e.c.	7.1
38.07	43.01	Steam Engines and Turbines	17.2
38.07	43.02	Internal Combustion Engines, n.e.c.	8.7
38.07	44.00	Farm Machinery	12.1
38.07	45.01	Construction Machinery	4.1
38.07	45.02	Mining Machinery	1.0
38.07	45.03	Oil Field Machinery	1.6
38.07	46.01	Elevators and Moving Stairways	1.6
38.07	46.02	Conveyors and Conveying Equipment	4.3
38.07	46.03	Hoists, Cranes, and Monorails	2.5
38.07	46.04	Industrial Trucks and Tractors	.7

INTERINDUSTRY RELATIONSHIPS OF COPPER ROLLING AND DRAWING, UNITED STATES, 1967
(Continued)

From	To	Description	($ millions)
38.07	47.01	Machine Tools, Metal Cutting Types	2.3
38.07	47.02	Machine Tools, Metal Forming Types	1.0
38.07	47.03	Special Dies and Tools and Machine Tool Accessories	7.3
38.07	47.04	Metalworking Machinery, n.e.c.	6.4
38.07	48.01	Food Products Machinery	1.3
38.07	48.02	Textile Machinery	3.0
38.07	48.04	Paper Industries Machinery	10.0
38.07	48.05	Printing Trades Machinery	2.4
38.07	48.06	Special Industry Machinery, n.e.c.	10.2
38.07	49.01	Pumps and Compressors	11.7
38.07	49.02	Ball and Roller Bearings	3.0
38.07	49.03	Blowers and Fans	4.5
38.07	49.04	Industrial Patterns	.2
38.07	49.05	Power Transmission Equipment	6.0
38.07	49.06	Industrial Furnaces and Ovens	5.6
38.07	49.07	General Industrial Machinery, n.e.c.	4.2
38.07	50.00	Machine Shop Products	30.6
38.07	51.01	Computing and Related Machines	2.9
38.07	51.02	Typewriters	.2
38.07	51.03	Scales and Balances	.2
38.07	51.04	Office Machines, n.e.c.	.9
38.07	52.01	Automatic Merchandising Machines	.2
38.07	52.02	Commercial Laundry Equipment	.3
38.07	52.03	Refrigeration Machinery	135.2
38.07	52.04	Measuring and Dispensing Pumps	1.2
38.07	52.05	Service Industry Machines, n.e.c.	1.6
38.07	53.01	Electric Measuring Instruments	4.3
38.07	53.02	Transformers	17.6
38.07	53.03	Switchgear and Switchboard Apparatus	46.2

INTERINDUSTRY RELATIONSHIPS OF COPPER ROLLING AND DRAWING, UNITED STATES, 1967

(Continued)

From	To	Description	($ millions)
38.07	53.04	Motors and Generators	27.7
38.07	53.05	Industrial Controls	6.8
38.07	53.06	Welding Apparatus	9.5
38.07	53.07	Carbon and Graphite products	.6
38.07	53.08	Electrical Industrial Apparatus, n.e.c.	4.4
38.07	54.01	Household Cooking Equipment	1.4
38.07	54.02	Household Refrigerators and Freezers	1.4
38.07	54.03	Household Laundry Equipment	1.3
38.07	54.04	Electric Housewares and Fans	3.2
38.07	54.05	Household Vacuum Cleaners	.9
38.07	54.06	Sewing Machines	.3
38.07	54.07	Household Appliances, n.e.c.	3.6
38.07	55.01	Electric Lamps	.9
38.07	55.02	Lighting Fixtures	9.0
38.07	55.03	Wiring Devices	35.7
38.07	56.01	Radio and Television Receiving Sets	.8
38.07	56.03	Telephone and Telegraph Apparatus	28.1
38.07	56.04	Radio and Television Communication Equipment	6.1
38.07	57.01	Electron Tubes	2.5
38.07	57.02	Semiconductors	1.8
38.07	57.03	Electronic Components, n.e.c.	27.4
38.07	58.03	X-Ray Apparatus and Tubes	.9
38.07	58.04	Engine Electrical Equipment	9.9
38.07	58.05	Electrical Equipment, n.e.c.	4.9
38.07	59.01	Truck and Bus Bodies	3.8
38.07	59.02	Truck Trailers	.6
38.07	59.03	Motor Vehicles and Parts	119.9
38.07	60.01	Aircraft	1.6

INTERINDUSTRY RELATIONSHIPS OF COPPER ROLLING AND DRAWING, UNITED STATES, 1967

(Continued)

From	To	Description	($ millions)
38.07	60.02	Aircraft Engines and Parts	2.1
38.07	60.04	Aircraft Equipment, n.e.c.	8.8
38.07	61.01	Shipbuilding and Repairing	14.4
38.07	61.02	Boatbuilding and Repairing	.7
38.07	61.03	Locomotives and Parts	9.1
38.07	61.04	Railroad and Street Cars	2.3
38.07	61.05	Motorcycles, Bicycles and Parts	.2
38.07	61.06	Trailer Coaches	4.4
38.07	61.07	Transportation Equipment, n.e.c.	1.0
38.07	62.01	Engineering and Scientific Instruments	1.2
38.07	62.02	Mechanical Measuring Devices	12.7
38.07	62.03	Automatic Temperature Controls	16.6
38.07	63.03	Photographic Equipment and Supplies	1.0
38.07	64.01	Jewelry, Including Costume, and Silverware	19.8
38.07	64.02	Musical Instruments and Parts	2.0
38.07	64.03	Games, Toys, Etc.	.7
38.07	64.04	Sporting and Athletic Goods, n.e.c.	3.2
38.07	64.07	Buttons, Needles, Pins and Fasteners	22.6
38.07	64.12	Miscellaneous Manufactures, n.e.c.	15.0
38.07	65.01	Railroads and Related Services	6.0
38.07	68.01	Electric Utilities	.7
38.07	69.01	Wholesale Trade	2.4
38.07	71.02	Real Estate	4.1
38.07	83.00	Scrap, Used and Secondhand Goods	33.2
38.07	88.00	Total Intermediate Output	2,582.0
38.07	93.00	Net Inventory Change	- .3
38.07	94.00	Net Exports	18.5
38.07	97.10	Federal Government Purchases, Defense	4.5

INTERINDUSTRY RELATIONSHIPS OF COPPER ROLLING AND DRAWING, UNITED STATES, 1967
(Continued)

From	To	Description	($ millions)
38.07	97.20	Federal Government Purchases, Other	3.9
38.07	99.02	Total Final Demand	26.6
38.07	99.03	Total Output	2,608.6
38.07	99.04	Transfers-Out	258.9

SOURCE: U. S. Department of Commerce, Input-Output Structure of the U. S. Economy: 1967, Volume I, Transactions Data for Detailed Industries, A Supplement to the Survey of Current Business, 1974.

APPENDIX D

MODEL FORECASTS (1974-1987)

APPENDIX D-1: BASELINE
APPENDIX D-2: CONSTRAINED CAPACITY
APPENDIX D-3: REDUCED CAPACITY
APPENDIX D-4: DEFINITION OF VARIABLES

APPENDIX D-1

BASELINE

EXOGENOUS AND ENDOGENOUS VARIABLES LISTED BELOW

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YEAR   CONST      RPAL       YUD       RPLME    YUD/YGR    DUMST2     DIGOV    IRR (-1)     QFAB      DSTE2

1954   1.0000    24.555    43.082    58.525    1.3548    .50000    199.30    87.700    2113.0    1.5000
1955   1.0000    32.411    49.296    79.356    1.3469    1.5000    23.600    47.100    2565.0    .00000
1956   1.0000    28.855    50.953    69.752    1.2867    .00000    49.500    61.600    2435.5    .00000
1957   1.0000    23.002    51.284    44.777    1.2298    .00000    79.000    120.60    2214.0    .00000
1958   1.0000    20.745    44.905    39.699    1.0395    .00000    124.70    181.00    2021.5    4.6700
1959   1.0000    22.763    51.533    47.139    1.1130    4.6700    4.5000    80.700    2383.0    .75000
1960   1.0000    21.320    52.444    48.689    1.0144    .75000    6.0000    64.800    2119.5    .00000
1961   1.0000    18.924    51.450    45.642    .93716    .00000   -5.0000    139.30    2213.0    .00000
1962   1.0000    17.562    57.166    46.631    .99767    .00000   -7.4000    79.800    2423.0    .00000
1963   1.0000    18.372    60.895    46.646    1.0321    .00000   -11.400    117.40    2540.5    2.0000
1964   1.0000    19.306    65.451    69.101    1.0132    2.0000   -27.300    76.900    2863.0    .00000
1965   1.0000    22.770    73.322    90.972    1.0751    .00000   -122.50    45.600    3052.5    .00000
1966   1.0000    19.369    82.021    104.93    1.1853    .00000   -445.00    60.800    3398.5    5.5000
1967   1.0000    15.589    82.850    76.148    1.2311    5.5000   -177.20    65.700    2903.0    3.0000
1968   1.0000    14.472    87.407    80.416    1.1623    3.0000   -13.800    55.400    2911.0    .00000
1969   1.0000    17.991    91.135    91.460    1.0659    .00000   -8.0000    56.600    3274.0    .00000
1970   1.0000    14.515    84.093    84.768    .93333    .00000    .00000    45.900    2820.0    1.0000
1971   1.0000    10.593    82.353    62.581    .89709    1.0000   -1.8000    160.60    2909.5    .00000
1972   1.0000    9.2281    89.809    59.578    .94140    .00000    .00000    103.00    3234.0    .00000
1973   1.0000    13.018    101.08    94.261    .99387    .00000   -33.800    157.40    3596.5    2.2500
1974   1.0000    16.180    100.00    94.261    1.0000    2.2500   -182.50    49.100    3097.0    .00000
1975   1.0000    9.2830    86.950    93.000    .96930   -.00000    .00000   -.00000    2315.0    .00000
1976   1.0000    13.797    96.580    50.224    1.0343   -.00000    .00000   -.00000    2993.3    1.5000
1977   1.0000    15.000    101.68    50.000    1.0591   -.00000    .00000   -.00000    3135.5    .00000
1978   1.0000    15.000    105.22    50.000    1.0749   -.00000    .00000   -.00000    3260.9    .00000
1979   1.0000    17.500    108.38    75.000    1.0801   -.00000    .00000   -.00000    3358.7    .75000
1980   1.0000    17.500    112.44    75.000    1.0853   -.00000    .00000   -.00000    3484.7    .00000
1981   1.0000    17.500    116.66    75.000    1.0905   -.00000    .00000   -.00000    3615.4    .00000
1982   1.0000    17.500    121.03    75.000    1.0957   -.00000    .00000   -.00000    3751.0    1.5000
1983   1.0000    17.500    125.57    75.000    1.1010   -.00000    .00000   -.00000    3891.7    .00000
1984   1.0000    17.500    130.28    75.000    1.1064   -.00000    .00000   -.00000    4037.6    .00000
1985   1.0000    17.500    135.17    75.000    1.1117   -.00000    .00000   -.00000    4189.0    .00000
1986   1.0000    17.500    140.24    75.000    1.1117   -.00000    .00000   -.00000    4346.1    .00000
1987   1.0000    17.500    145.50    75.000    1.1117   -.00000    .00000   -.00000    4509.1    .00000
1988   1.0000   -.00000   -.00000   -.00000   -.00000   -.00000    .00000   -.00000   -.00000    .00000
1989   1.0000   -.00000   -.00000   -.00000   -.00000   -.00000    .00000   -.00000   -.00000    .00000
1990   1.0000   -.00000   -.00000   -.00000   -.00000   -.00000    .00000   -.00000   -.00000    .00000
1991   1.0000   -.00000   -.00000   -.00000   -.00000   -.00000    .00000   -.00000   -.00000    .00000
1992   1.0000   -.00000   -.00000   -.00000   -.00000   -.00000    .00000   -.00000   -.00000    .00000
1993   1.0000   -.00000   -.00000   -.00000   -.00000   -.00000    .00000   -.00000   -.00000    .00000
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YEAR    IP(-1)    IRS(-1)     QD(-1)   IPOLLM+M   IPRODM+M   IPOLLS+R   KAPSR    KAPPR     DOLKAP    CAPAC

1954    172.00    60.000      2287.0   .00000     .00000     .00000     200.00   1696.0    535.76    .00000
1955    146.00    35.000      1916.5   .00000     .00000     .00000     206.00   1656.0    540.64    .00000
1956    170.00    56.000      2418.7   .00000     .00000     .00000     271.00   1799.0    545.35    .00000
1957    177.00    59.000      2365.0   .00000     .00000     .00000     271.00   1793.0    550.11    .00000
1958    175.00    43.000      2106.4   .00000     .00000     .00000     271.00   1810.5    554.90    .00000
1959    179.00    49.000      1974.6   .00000     .00000     .00000     296.00   1812.5    559.74    .00000
1960    140.00    71.000      2318.6   .00000     .00000     .00000     296.00   2013.0    564.62    .00000
1961    148.00    62.000      2079.3   .00000     .00000     .00000     313.50   2017.5    569.54    .00000
1962    152.00    43.000      2170.0   .00000     .00000     .00000     313.50   2027.5    574.51    .00000
1963    157.00    59.000      2361.1   .00000     .00000     .00000     317.50   2016.5    579.52    .00000
1964    149.00    47.000      2565.7   .00000     .14600+09  .00000     317.50   2016.5    584.57    .24292+10
1965    159.00    53.000      2775.0   .00000     .15800+09  .00000     317.50   2016.5    589.67    .00000
1966    168.00    49.000      2995.4   .00000     .17100+09  .00000     317.50   2102.5    594.81    .00000
1967    231.00    52.000      3368.6   .00000     .18400+09  .00000     314.00   2112.5    600.00    .00000
1968    182.00    48.000      2850.4   .00000     .19700+09  .00000     319.00   2208.0    645.42    .00000
1969    168.00    42.000      2813.5   .00000     .21100+09  .00000     304.00   2339.0    694.28    .00000
1970    178.00    57.000      3164.2   .00000     .22500+09  .20900+08  304.00   2372.0    746.84    .00000
1971    242.00    68.000      2930.5   .00000     .24000+09  .30000+08  304.00   2372.0    803.38    .00000
1972    229.00    51.000      2956.0   .00000     .25700+09  .14640+09  304.00   2489.0    864.20    .00000
1973    167.00    46.000      3266.2   .00000     .45450+09  .20460+09  304.00   2419.0    929.62    .00000
1974    167.00    42.000      3481.7   .00000     .46500+09  .22600+09  304.00   2546.0    1600.0    .43000+10
1975    -.00000   -.00000     3106.2   .00000     .37100+09  .00000     304.00   -.00000   1600.0    .00000
1976    -.00000   -.00000     -.00000  .00000     .40000+09  .00000     304.00   -.00000   1600.0    .00000
1977    -.00000   -.00000     -.00000  .00000     .40000+09  .00000     304.00   -.00000   1600.0    .00000
1978    -.00000   -.00000     -.00000  .00000     .40000+09  .00000     304.00   -.00000   1600.0    .00000
1979    -.00000   -.00000     -.00000  .00000     .40000+09  .00000     304.00   -.00000   1600.0    .00000
1980    -.00000   -.00000     -.00000  .00000     .40000+09  .00000     304.00   -.00000   1600.0    .00000
1981    -.00000   -.00000     -.00000  .00000     .40000+09  .00000     304.00   -.00000   1600.0    .00000
1982    -.00000   -.00000     -.00000  .00000     .40000+09  .00000     304.00   -.00000   1600.0    .00000
1983    -.00000   -.00000     -.00000  .00000     .40000+09  .00000     304.00   -.00000   1600.0    .00000
1984    -.00000   -.00000     -.00000  .00000     .40000+09  .00000     304.00   -.00000   1600.0    .00000
1985    -.00000   -.00000     -.00000  .00000     .40000+09  .00000     304.00   -.00000   1600.0    .00000
1986    -.00000   -.00000     -.00000  .00000     .40000+09  .00000     304.00   -.00000   1600.0    .00000
1987    -.00000   -.00000     -.00000  .00000     .40000+09  .00000     304.00   -.00000   1600.0    .00000
1988    -.00000   -.00000     -.00000  .00000     .00000     .00000     304.00   -.00000   1600.0    .00000
1989    -.00000   -.00000     -.00000  .00000     .00000     .00000     304.00   -.00000   1600.0    .00000
1990    -.00000   -.00000     -.00000  .00000     .00000     .00000     304.00   -.00000   1600.0    .00000
1991    -.00000   -.00000     -.00000  .00000     .00000     .00000     304.00   -.00000   1600.0    .00000
1992    -.00000   -.00000     -.00000  .00000     .00000     .00000     304.00   -.00000   1600.0    .00000
1993    -.00000   -.00000     -.00000  .00000     .00000     .00000     304.00   -.00000   1600.0    .00000
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YEAR    FCCOEF1     FCCOEF2     FCCOEF3     FCCOEF4     FCCOEF5     FCCOEF6      DEP1        DEP2        REP        QCU

1954   .22120      .22120      .22120      .22120      .22120      .22120      .15700-01   .15700-01   .26600-01   835.50
1955   .22120      .22120      .22120      .22120      .22120      .22120      .15700-01   .15700-01   .26600-01   998.60
1956   .22120      .22120      .22120      .22120      .22120      .22120      .15700-01   .15700-01   .26600-01   1104.2
1957   .22120      .22120      .22120      .22120      .22120      .22120      .15700-01   .15700-01   .26600-01   1086.9
1958   .22120      .22120      .22120      .22120      .22120      .22120      .15700-01   .15700-01   .26600-01   979.30
1959   .22120      .22120      .22120      .22120      .22120      .22120      .15700-01   .15700-01   .26600-01   824.80
1960   .22120      .22120      .22120      .22120      .22120      .22120      .15700-01   .15700-01   .26600-01   1080.2
1961   .22120      .22120      .22120      .22120      .22120      .22120      .15700-01   .15700-01   .26600-01   1165.2
1962   .22120      .22120      .22120      .22120      .22120      .22120      .15700-01   .15700-01   .26600-01   1228.4
1963   .22120      .22120      .22120      .22120      .22120      .22120      .15700-01   .15700-01   .26600-01   1213.2
1964   .19460      .19460      .19460      .19460      .19460      .19460      .15700-01   .15700-01   .26600-01   1246.8
1965   .22120      .22120      .22120      .22120      .22120      .22120      .15700-01   .15700-01   .26600-01   1351.7
1966   .10000+00   .10000+00   .10000+00   .10000+00   .10000+00   .10000+00   .15700-01   .15700-01   .26600-01   1429.2
1967   .25000-01   .25000-01   .25000-01   .25000-01   .25000-01   .25000-01   .15700-01   .15700-01   .26600-01   954.10
1968   .17460      .17460      .17460      .17460      .17460      .17460      .15700-01   .15700-01   .26600-01   1204.6
1969   .25690      .25690      .25690      .25690      .25690      .25690      .15700-01   .15700-01   .26600-01   1544.6
1970   .27310      .27310      .27310      .27310      .27310      .27310      .15700-01   .15700-01   .26600-01   1719.7
1971   .10000+00   .10000+00   .10000+00   .10000+00   .10000+00   .10000+00   .15700-01   .15700-01   .26600-01   1522.2
1972   .16850      .16850      .16850      .16850      .16850      .16850      .15700-01   .15700-01   .26600-01   1664.8
1973   .20380      .20380      .20380      .20380      .20380      .20380      .15700-01   .15700-01   .26600-01   1717.9
1974   .82800-01   .82800-01   .82800-01   .23280      .23280      .23280      .30930-01   .15700-01   .53200-01   1593.6
1975   .52800-01   .52800-01   .52800-01  -.00000     -.00000     -.00000      .19100-02   .15700-01   .53200-01  -.00000
1976   .82800-01   .82800-01   .82800-01  -.00000     -.00000     -.00000      .30000-01   .15700-01   .53200-01  -.00000
1977   .82800-01   .82800-01   .82800-01  -.00000     -.00000     -.00000      .30000-01   .15700-01   .53200-01  -.00000
1978   .82800-01   .17000      .82800-01  -.00000     -.00000     -.00000      .30000-01   .15700-01   .53200-01  -.00000
1979   .16280      .17000      .16280     -.00000     -.00000     -.00000      .30000-01   .15700-01   .53200-01  -.00000
1980   .16280      .17000      .16280     -.00000     -.00000     -.00000      .30000-01   .15700-01   .53200-01  -.00000
1981   .16280      .17000      .16280     -.00000     -.00000     -.00000      .30000-01   .15700-01   .53200-01  -.00000
1982   .20280      .17000      .20280     -.00000     -.00000     -.00000      .30000-01   .15700-01   .53200-01  -.00000
1983   .20280      .17000      .20280     -.00000     -.00000     -.00000      .30000-01   .15700-01   .53200-01  -.00000
1984   .20280      .17000      .20280     -.00000     -.00000     -.00000      .30000-01   .15700-01   .53200-01  -.00000
1985   .20280      .17000      .20280     -.00000     -.00000     -.00000      .30000-01   .15700-01   .53200-01  -.00000
1986   .23280      .17000      .23280     -.00000     -.00000     -.00000      .30000-01   .15700-01   .53200-01  -.00000
1987   .23280      .17000      .23280     -.00000     -.00000     -.00000      .30000-01   .15700-01   .53200-01  -.00000
1988  -.00000     -.00000     -.00000     -.00000     -.00000     -.00000      .30000-01   .15700-01   .53200-01  -.00000
1989  -.00000     -.00000     -.00000     -.00000     -.00000     -.00000      .30000-01   .15700-01   .53200-01  -.00000
1990  -.00000     -.00000     -.00000     -.00000     -.00000     -.00000      .30000-01   .15700-01   .53200-01  -.00000
1991  -.00000     -.00000     -.00000     -.00000     -.00000     -.00000      .30000-01   .15700-01   .53200-01  -.00000
1992  -.00000     -.00000     -.00000     -.00000     -.00000     -.00000      .30000-01   .15700-01   .53200-01  -.00000
1993  -.00000     -.00000     -.00000     -.00000     -.00000     -.00000      .30000-01   .15700-01   .53200-01  -.00000
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YEAR     NETY        CCAP1        FIPDE     VARCOS1    VARCOS2    VARCOS3    VARCOS4      QD        RPENJ       NE

1954  .18549+06   .19620        84.000    -.00000    -.00000    -.00000    -.00000    1916.5     55.568     124.70
1955  .33379+06   .46990        85.900    -.00000    -.00000    -.00000    -.00000    2418.7     67.769     40.800
1956  .42300+06   .23100        91.800    -.00000    -.00000    -.00000    -.00000    2365.0     71.026     83.300
1957  .22613+06 -.88800-01      97.500    -.00000    -.00000    -.00000    -.00000    2106.4     48.357     274.00
1958  .17079+06   .45500-01     100.00    -.00000    -.00000    -.00000    -.00000    1974.6     41.203     287.40
1959  .20223+06   .17250        102.00    -.00000    -.00000    -.00000    -.00000    2318.6     49.289    -32.900
1960  .22508+06 -.22700-01      102.20    -.00000    -.00000    -.00000    -.00000    2079.3     50.616     438.00
1961  .20393+06   .11540        102.10    -.00000    -.00000    -.00000    -.00000    2170.0     47.500     480.50
1962  .21782+06   .62000-01     102.30    -.00000    -.00000    -.00000    -.00000    2361.1     48.633     269.80
1963  .22045+06   .15450        102.30    -.00000    -.00000    -.00000    -.00000    2565.7     48.633     228.40
1964  .27626+06   .19830        103.00     36.000    -.00000    -.00000    -.00000    2775.0     50.204     267.70
1965  .37756+06   .12170        103.90     37.000    -.00000    -.00000    -.00000    2995.4     54.320     256.10
1966  .49100+06   .90400-01     106.00     38.000    -.00000    -.00000    -.00000    3368.6     54.903     135.10
1967  .33791+06   .63000-01     109.30     39.000    -.00000    -.00000    -.00000    2850.4     56.814    -123.60
1968  .42022+06   .16590        112.00     40.000    -.00000    -.00000    -.00000    2813.5     60.086    -72.700
1969  .55193+06   .17490        115.20     41.000    -.00000    -.00000    -.00000    3164.2     65.577     130.70
1970  .51607+06   .11750        120.30     42.000    -.00000    -.00000    -.00000    2930.5     76.556     168.90
1971  .61506+06 -.49500-01      124.50     43.000    -.00000    -.00000    -.00000    2956.0     65.324     74.400
1972  .38322+06   .61700-01     126.50     44.000    -.00000    -.00000    -.00000    3266.2     62.118     29.500
1973  .59883+06   .91100-01     130.00     45.000    -.00000    -.00000    -.00000    3481.7     68.669     72.600
1974  .88136+06   .76400-01     143.50     43.000    -.00000    -.00000    -.00000    3106.2    -.00000    -108.50
1975 -.00000      .13180       -.00000     43.000    -.00000    -.00000    -.00000   -.00000    -.00000    -.00000
1976 -.00000      .14360       -.00000     43.000    -.00000    -.00000    -.00000   -.00000    -.00000    -.00000
1977 -.00000      .14440       -.00000     43.000    -.00000    -.00000    -.00000   -.00000    -.00000    -.00000
1978 -.00000      .15600       -.00000     43.000    -.00000    -.00000    -.00000   -.00000    -.00000    -.00000
1979 -.00000      .15870       -.00000     43.000    -.00000    -.00000    -.00000   -.00000    -.00000    -.00000
1980 -.00000      .14890       -.00000     43.000    -.00000    -.00000    -.00000   -.00000    -.00000    -.00000
1981 -.00000      .13810       -.00000     43.000    -.00000    -.00000    -.00000   -.00000    -.00000    -.00000
1982 -.00000      .13280       -.00000     43.000    -.00000    -.00000    -.00000   -.00000    -.00000    -.00000
1983 -.00000      .13410       -.00000     43.000    -.00000    -.00000    -.00000   -.00000    -.00000    -.00000
1984 -.00000      .13410       -.00000     43.000    -.00000    -.00000    -.00000   -.00000    -.00000    -.00000
1985 -.00000      .13410       -.00000     43.000    -.00000    -.00000    -.00000   -.00000    -.00000    -.00000
1986 -.00000      .13410       -.00000     43.000    -.00000    -.00000    -.00000   -.00000    -.00000    -.00000
1987 -.00000      .13410       -.00000     43.000    -.00000    -.00000    -.00000   -.00000    -.00000    -.00000
1988 -.00000      .13410       -.00000     43.000    -.00000    -.00000    -.00000   -.00000    -.00000    -.00000
1989 -.00000      .13410       -.00000     43.000    -.00000    -.00000    -.00000   -.00000    -.00000    -.00000
1990 -.00000      .13410       -.00000     43.000    -.00000    -.00000    -.00000   -.00000    -.00000    -.00000
1991 -.00000      .13410       -.00000     43.000    -.00000    -.00000    -.00000   -.00000    -.00000    -.00000
1992 -.00000      .13410       -.00000     43.000    -.00000    -.00000    -.00000   -.00000    -.00000    -.00000
1993 -.00000      .13410       -.00000     43.000    -.00000    -.00000    -.00000   -.00000    -.00000    -.00000
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YEAR	QR	DELIF	DELIRR	DELIRS	QPR	RPSR	QSR	RPS	QSNR	RPPUT1
1954	1418.4	-26.000	-40.600	-25.000	1220.1	64.645	198.30	45.929	742.00	46.753
1955	1562.8	24.000	14.500	21.000	1320.7	77.043	242.10	60.774	938.80	57.375
1956	1687.8	7.0000	59.000	3.0000	1467.2	68.903	220.60	53.617	855.40	76.868
1957	1676.1	-2.0000	60.400	-16.000	1422.1	54.095	254.00	32.843	808.70	52.575
1958	1579.5	4.0000	-100.30	6.0000	1373.1	48.912	206.40	28.119	735.30	38.420
1959	1331.5	-39.000	-75.900	22.000	1071.6	53.035	259.90	35.646	883.10	45.210
1960	1794.6	8.0000	74.500	-9.0000	1559.6	50.790	235.00	33.417	831.60	49.021
1961	1813.9	4.0000	-59.500	-19.000	1609.2	52.040	204.70	34.577	778.40	43.943
1962	1884.5	5.0000	37.600	16.007	1677.6	52.575	206.90	34.297	804.10	48.061
1963	1884.4	-8.0000	-40.500	-12.000	1639.7	53.544	244.70	35.267	849.00	45.343
1964	1990.4	10.000	-31.300	6.0000	1740.7	56.519	249.70	40.810	989.70	48.272
1965	2214.8	9.0000	15.200	-4.0000	1864.0	73.662	276.80	53.498	1025.6	55.669
1966	2183.3	63.000	4.9000	3.0000	1896.5	87.523	286.80	67.790	1013.1	82.559
1967	1526.6	-49.000	-10.300	-4.0000	1251.4	68.584	275.20	49.264	932.10	77.441
1968	1839.0	-14.000	1.2000	-6.0000	1546.3	67.136	292.70	47.035	982.60	73.855
1969	2214.9	10.000	-10.700	15.000	1937.0	78.477	277.90	59.161	1082.9	67.260
1970	2242.7	64.000	114.70	11.000	1975.1	70.917	267.60	52.342	978.50	69.935
1971	1962.4	-13.000	-57.600	-17.000	1733.3	60.422	229.10	35.018	971.90	60.485
1972	2258.5	-62.000	54.400	-5.0000	2011.4	72.426	247.10	47.883	1062.2	60.486
1973	2312.6	.00000	-108.30	-4.0000	2027.2	84.241	285.40	58.579	1119.5	60.329
1974	2136.5	75.000	145.80	1.0000	1838.8	79.880	297.70	54.880	1025.1	81.640
1975	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1976	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1977	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1978	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1979	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1980	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1981	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1982	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1983	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1984	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1985	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1986	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1987	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1988	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1989	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1990	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1991	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1992	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1993	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000

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                           SUMMARY FOR YEARS: 1974 - 1987
                                   MOST PROBABLE
                      PARAMETRIC SOLUTIONS FOR THE ENDOGENOUS VARIABLES

                                   1974        1975        1976        1977        1978

QD - TOTAL CONSUMPTION IN US   3397.846    2503.437    3317.901    3455.103    3502.930

RPEMJ - DEFL. AVE REF. PRICE     77.196      54.364      55.968      56.397      48.848

NE - NET EXPORTS SCRAP + REF.  -167.099      61.963    -222.154    -239.593    -241.682

QR - TOTAL PRODUCTION REFINED  2077.928    1433.310    2099.293    2297.015    2463.919

DELIF - STOCK CHANGE FABRICAT.    -.380      36.979      25.656      10.793       9.965

DELIRR - STOCK CHANGE REFINER.  194.184    -223.964    -163.414     -59.607       5.841

DELIRS - STOCK CHANGE SCRAP      65.326      -5.031       6.770       4.480      -4.474

QPR - TOTAL PROD. PRIMARY REF. 1792.744    1216.281    1876.421    2060.721    2359.380

RPSR - PRICE SECONDARY REFINED   88.507      70.828      57.808      58.232      56.487

QSR - PROD REFINED FROM SCRAP   285.185     217.029     222.872     236.294     223.984

RPS - REAL PRICE OF SCRAP        69.565      47.013      41.198      41.876      36.771

QSNR - SCRAP RECEIPTS NOT REF. 1229.450     940.074     865.466     874.162     808.660

RPFUT1 - DEFL FUT PRICE (JAN)    71.238      68.086      48.636      48.534      48.534

 QUANTITY ESTIMATES IN 1000'S OF SHORT TONS
 PRICE ESTIMATES IN CENTS PER POUND
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                          SUMMARY FOR YEARS: 1974 - 1987
                                  MOST PROBABLE
                    PARAMETRIC SOLUTIONS FOR THE ENDOGENOUS VARIABLES

                                    1979        1980        1981        1982        1983

QD - TOTAL CONSUMPTION IN US      3792.373    3901.041    4027.337    4142.673    4221.751

RPEMJ - DEFL. AVE REF. PRICE        68.893      72.230      72.863      74.757      76.596

NE - NET EXPORTS SCRAP + REF.     -274.285    -313.768    -361.530    -406.295    -355.960

QR - TOTAL PRODUCTION REFINED     2434.578    2499.613    2558.605    2625.414    2727.444

DELIF - STOCK CHANGE FABRICAT.      11.909       6.379       7.233      15.626       5.021

DELIRR - STOCK CHANGE REFINER.     -23.265      14.142       2.085       6.244       8.908

DELIRS - STOCK CHANGE SCRAP          5.806       3.745       1.746       2.247       1.657

QPR - TOTAL PROD. PRIMARY REF.    2191.563    2256.021    2314.668    2375.430    2477.489

RPSR - PRICE SECONDARY REFINED      75.611      77.771      78.176      79.289      80.485

QSR - PROD REFINED FROM SCRAP      243.015     243.592     243.936     249.984     249.955

RPS - REAL PRICE OF SCRAP           57.759      60.406      60.900      62.211      63.680

QSNR - SCRAP RECEIPTS NOT REF.    1077.961    1111.926    1118.267    1135.081    1153.932

RPFUT1 - DEFL FUT PRICE (JAN)       59.902      59.902      59.902      59.902      59.902

QUANTITY ESTIMATES IN 1000'S OF SHORT TONS
PRICE ESTIMATES IN CENTS PER POUND
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                              SUMMARY FOR YEARS: 1974 - 1987
                                       MOST PROBABLE
                        PARAMETRIC SOLUTIONS FOR THE ENDOGENOUS VARIABLES

                                  1984         1985         1986         1987

QD - TOTAL CONSUMPTION IN US    4405.506     4567.948     4689.812     4864.335
RPENJ - DEFL. AVE REF. PRICE      73.912       74.796       78.346       77.194
NE - NET EXPORTS SCRAP + REF.   -474.260     -513.830     -485.773     -571.204
QR - TOTAL PRODUCTION REFINED   2814.747     2936.870     3054.374     3149.329
DELIF - STOCK CHANGE FABRICAT.     6.874        8.084        8.932        9.579
DELIRR - STOCK CHANGE REFINER.     4.016       10.790        9.847        5.450
DELIRS - STOCK CHANGE SCRAP        -.630         .049        2.099         .216
QPR - TOTAL PROD. PRIMARY REF.  2565.485     2688.398     2801.672     2897.264
RPSR - PRICE SECONDARY REFINED    78.755       79.346       81.563       80.828
QSR - PROD REFINED FROM SCRAP    249.262      248.472      252.702      252.065
RPS - REAL PRICE OF SCRAP         61.562       62.296       64.974       64.079
QSNR - SCRAP RECEIPTS NOT REF.  1126.760     1136.171     1170.543     1159.048
RPFUT1 - DEFL FUT PRICE (JAN)     59.902       59.902       59.902       59.902

QUANTITY ESTIMATES IN 1000'S OF SHORT TONS
PRICE ESTIMATES IN CENTS PER POUND
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APPENDIX D-2

CONSTRAINED CAPACITY

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                                  SUMMARY FOR YEARS: 1974 - 1987
                                          MOST PROBABLE
                           PARAMETRIC SOLUTIONS FOR THE ENDOGENOUS VARIABLES

                                   1974          1975          1976          1977          1978

QD - TOTAL CONSUMPTION IN US     3396.866      2466.669      3281.998      3405.940      3415.772
RPEMJ - DEPL. AVE REF. PRICE       77.270        57.174        58.712        59.412        54.175
NE - NET EXPORTS SCRAP + REF.    -167.396        50.824      -233.031      -251.546      -264.385
QR - TOTAL PRODUCTION REFINED    2076.045      1362.271      2024.275      2207.524      2298.847
DELIF - STOCK CHANGE FABRICAT.      -.380        36.979        25.656        10.793         9.965
DELIRR - STOCK CHANGE REFINER.    194.035      -228.596      -168.511       -59.450         5.503
DELIRS - STOCK CHANGE SCRAP        65.393        -3.906         7.944         5.078        -9.498
QPR - TOTAL PROD. PRIMARY REF.   1790.588      1146.086      1801.627      1971.195      2236.129
RPSR - PRICE SECONDARY REFINED     88.545        72.235        59.419        60.112        59.828
QSR - PROD REFINED FROM SCRAP     285.457       216.185       222.649       236.330       171.305
RPS - REAL PRICE OF SCRAP          69.606        48.542        43.093        44.146        40.656
QSNR - SCRAP RECEIPTS NOT REF.   1229.973       959.699       889.780       903.291       858.510
RPFUT1 - DEPL FUT PRICE (JAN)      71.238        68.086        48.636        48.534        48.534

QUANTITY ESTIMATES IN 1000'S OF SHORT TONS
PRICE ESTIMATES IN CENTS PER POUND
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SUMMARY FOR YEARS: 1974 - 1987
MOST PROBABLE
PARAMETRIC SOLUTIONS FOR THE ENDOGENOUS VARIABLES

	1979	1980	1981	1982	1983
QD - TOTAL CONSUMPTION IN US	3708.627	3799.124	3899.703	3980.180	4019.263
RPEMJ - DEFL. AVE REF. PRICE	73.493	78.289	80.511	84.538	88.713
NE - NET EXPORTS SCRAP + REF.	-292.515	-337.782	-391.847	-445.066	-403.991
QR - TOTAL PRODUCTION REFINED	2288.181	2315.632	2324.352	2325.362	2355.758
DELIF - STOCK CHANGE FABRICAT.	11.909	6.379	7.233	15.626	5.021
DELIRR - STOCK CHANGE REFINER.	-27.588	12.650	-1.224	2.529	4.529
DELIRS - STOCK CHANGE SCRAP	10.522	6.336	3.580	3.766	3.641
QPR - TOTAL PROD. PRIMARY REF.	2039.615	2065.241	2072.407	2068.282	2095.633
RPSR - PRICE SECONDARY REFINED	78.496	81.577	82.987	85.484	88.119
QSR - PROD REFINED FROM SCRAP	248.566	250.391	251.945	257.080	260.125
RPS - REAL PRICE OF SCRAP	61.252	65.016	66.732	69.739	72.936
QSNR - SCRAP RECEIPTS NOT REF.	1122.775	1171.074	1193.092	1231.673	1272.705
RPFUT1 - DEFL FUT PRICE (JAN)	59.902	59.902	59.902	59.902	59.902

QUANTITY ESTIMATES IN 1000'S OF SHORT TONS
PRICE ESTIMATES IN CENTS PER POUND

SUMMARY FOR YEARS: 1974 - 1987
MOST PROBABLE
PARAMETRIC SOLUTIONS FOR THE ENDOGENOUS VARIABLES

	1984	1985	1986	1987
QD - TOTAL CONSUMPTION IN US	4162.628	4274.062	4344.416	4474.149
RPEMJ - DEFL. AVE REF. PRICE	88.290	92.237	98.670	99.876
NE - NET EXPORTS SCRAP + REF.	-531.250	-582.964	-566.333	-661.112
QR - TOTAL PRODUCTION REFINED	2370.954	2399.523	2426.921	2445.083
DELIF - STOCK CHANGE FABRICAT.	6.874	8.084	8.932	9.579
DELIRR - STOCK CHANGE REFINER.	-.053	4.903	4.862	1.062
DELIRS - STOCK CHANGE SCRAP	1.189	2.543	4.464	2.373
QPR - TOTAL PROD. PRIMARY REF.	2110.936	2136.591	2158.529	2175.533
RPSR - PRICE SECONDARY REFINED	87.846	90.332	94.351	95.098
QSR - PROD REFINED FROM SCRAP	260.018	262.932	268.393	269.549
RPS - REAL PRICE OF SCRAP	72.604	75.618	80.474	81.374
QSNR - SCRAP RECEIPTS NOT REF.	1268.433	1307.107	1369.421	1380.968
RPFUT1 - DEFL FUT PRICE (JAN)	59.902	59.902	59.902	59.902

QUANTITY ESTIMATES IN 1000'S OF SHORT TONS
PRICE ESTIMATES IN CENTS PER POUND

APPENDIX D-3

REDUCED CAPACITY

SUMMARY FOR YEARS: 1974 - 1987
MOST PROBABLE
PARAMETRIC SOLUTIONS FOR THE ENDOGENOUS VARIABLES

	1974	1975	1976	1977	1978
QD - TOTAL CONSUMPTION IN US	3396.866	2466.669	3281.998	3405.940	3415.772
RPEMJ - DEFL. AVE REF. PRICE	77.270	57.174	58.712	59.412	54.175
NE - NET EXPORTS SCRAP + REF.	-167.396	50.824	-233.031	-251.546	-264.385
QR - TOTAL PRODUCTION REFINED	2076.045	1362.271	2024.275	2207.524	2298.847
DELIF - STOCK CHANGE FABRICAT.	-.380	36.979	25.656	10.793	9.965
DELIRR - STOCK CHANGE REFINER.	194.035	-228.596	-168.511	-59.450	5.503
DELIRS - STOCK CHANGE SCRAP	65.393	-3.906	7.944	5.078	-9.498
QPR - TOTAL PROD. PRIMARY REF.	1790.588	1146.086	1801.627	1971.195	2236.129
RPSR - PRICE SECONDARY REFINED	88.545	72.235	59.419	60.112	59.828
QSR - PROD REFINED FROM SCRAP	285.457	216.185	222.649	236.330	171.305
RPS - REAL PRICE OF SCRAP	69.606	48.542	43.093	44.146	40.656
QSNR - SCRAP RECEIPTS NOT REF.	1229.973	959.699	889.780	903.291	858.510
RPFUT1 - DEFL FUT PRICE (JAN)	71.238	68.086	48.636	48.534	48.534

QUANTITY ESTIMATES IN 1000'S OF SHORT TONS
PRICE ESTIMATES IN CENTS PER POUND

SUMMARY FOR YEARS: 1974 - 1987
MOST PROBABLE
PARAMETRIC SOLUTIONS FOR THE ENDOGENOUS VARIABLES

	1979	1980	1981	1982	1983
QD - TOTAL CONSUMPTION IN US	3708.627	3799.124	3899.703	3982.563	3917.011
RPEMJ - DEFL. AVE REF. PRICE	73.493	78.289	80.511	84.356	96.577
NE - NET EXPORTS SCRAP + REF.	-292.515	-337.782	-391.847	-444.344	-435.164
QR - TOTAL PRODUCTION REFINED	2288.181	2315.632	2324.352	2329.989	2133.521
DELIF - STOCK CHANGE FABRICAT.	11.909	6.379	7.233	15.626	5.021
DELIRR - STOCK CHANGE REFINER.	-27.588	12.650	-1.224	2.927	-11.861
DELIRS - STOCK CHANGE SCRAP	10.522	6.336	3.580	3.563	7.968
QPR - TOTAL PROD. PRIMARY REF.	2039.615	2065.241	2072.407	2073.896	1867.300
RPSR - PRICE SECONDARY REFINED	78.496	81.577	82.987	85.390	93.058
QSR - PROD REFINED FROM SCRAP	248.566	250.391	251.945	256.093	266.221
RPS - REAL PRICE OF SCRAP	61.252	65.016	66.732	69.635	78.918
QSNR - SCRAP RECEIPTS NOT REF.	1122.775	1171.074	1193.092	1230.346	1349.453
RPFUT1 - DEFL FUT PRICE (JAN)	59.902	59.902	59.902	59.902	59.902

QUANTITY ESTIMATES IN 1000'S OF SHORT TONS
PRICE ESTIMATES IN CENTS PER POUND

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                                   SUMMARY FOR YEARS: 1974 - 1987
                                           MOST PROBABLE
                           PARAMETRIC SOLUTIONS FOR THE ENDOGENOUS VARIABLES

                                       1984          1985          1986          1987
QD - TOTAL CONSUMPTION IN US       4037.446      4147.159      4215.607      4345.245
RPEMJ - DEFL. AVE REF. PRICE         95.744        99.349       105.892       107.065
NE - NET EXPORTS SCRAP + REF.      -560.797      -611.153      -594.958      -689.611
QR - TOTAL PRODUCTION REFINED      2148.920      2173.921      2199.745      2217.660
DELIF - STOCK CHANGE FABRICAT.        6.874         8.084         8.932         9.579
DELIRR - STOCK CHANGE REFINER.        4.025         3.313         5.231          .930
DELIRS - STOCK CHANGE SCRAP           2.609         2.902         4.614         2.405
QPR - TOTAL PROD. PRIMARY REF.     1883.192      1905.544      1926.194      1943.035
RPSR - PRICE SECONDARY REFINED       92.530        94.793        98.876        99.602
QSR - PROD REFINED FROM SCRAP       265.728       268.376       273.551       274.625
RPS - REAL PRICE OF SCRAP            78.278        81.017        85.950        86.823
GSNR - SCRAP RECEIPTS NOT REF.     1341.239      1376.385      1439.681      1450.889
RPFUT1 - DEFL FUT PRICE (JAN)        59.902        59.902        59.902        59.902

QUANTITY ESTIMATES IN 1000'S OF SHORT TONS
PRICE ESTIMATES IN CENTS PER POUND
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APPENDIX D-4

DEFINITION OF VARIABLES

THE ECONOMETRIC SIMULATION AND IMPACT ANALYSIS MODEL OF THE UNITED STATES COPPER INDUSTRY: DEFINITION OF VARIABLES[1]

MARKET CLEARING MODULE
ENDOGENOUS VARIABLES

No.		
1.	ATC*	Average total cost, primary producers
2.	AVC*	Average variable cost, primary producers
3.	CAPP*	Capacity utilization rate for all refining, primary and secondary. (CAPP = QR/(KAPPR + KAPSR)).
4.	DIFF	Difference between the deflated LME price of copper and the EMJ price (RPLME - RPEMJ = DIFF) in ¢/lb.
5.	ER	U.S. exports of refined copper. Source: CDA, Table 1.
6.	FIXCOS*	Total fixed charges on fixed costs incurred by the primary producers as a whole in a given year.
7.	IF*	Fabricators stocks of copper, both scrap and refined (IF = IFS + IFR). ΔIF = IF(t) - IF9t-1) = DELIF
8.	IFR	Refined copper stocks held by wire mills, brass mills and other fabricators and semi-fabricators, end of year. Source: CDA, Table 1, item 16.
9.	IFS	Scrap stocks held by brass mills, foundries and other fabricators and semi-fabricators, end of year. Source: CDA, Table 2, item 3.
10.	IR	U.S. imports of refined copper. Source: CDA, Table 1.

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[1] All quantity series are expressed in thousands of short tons; the asterisk (*) denotes variables which appear explicitly in the model while those without (*) are intermediate variables used in computing those appearing in the model.

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11.	IRR*	Refined copper stocks held at refineries, end of year. Source: CDA, Table 1, item 6. $\Delta IRR = IRR(t) - IRR(t-1) = DELIRR$
12.	IRS	Scrap stocks held by smelters and refineries, end of year. Source: CDA, Table 2, item 3. $\Delta IRS = IRS(t) - IRS(t-1) = DELIRS$
13.	MRPEMJ*	Marginal revenue, primary producers.
14.	NE*	Net exports of copper, scrap and refined) (NE = NES + NER)
15.	NER	Net exports of refined copper from the U.S. (ER-IR).
16.	NES	Net export of scrap. Source: CDA, Table 2.
17.	PEMJ	Metals Week (formerly E&MJ Metal and Mining Markets) average domestic refinery price of electrolytic copper wire bars and ingot bars, FOB refinery; also tabulated in the Yearbook of the American Bureau of Metal Statistics (ABMS) as monthly average prices of copper, domestic refinery--New York--¢/lb.
18.	PFUT1	Simple average of Closing Future Price (¢/lb) of copper for all of the next 12 months reported starting in January of the year. Source: Wall Street Journal.
19.	PS	From 1956 on, dealers' buying price for #2 heavy copper scrap; before 1956, dealer's buying price for #1 heavy copper scrap. ¢/lb--Metal Statistics.

20.	QD*	Total consumption of refined and scrap copper in the U.S. by ingot makers, brass mills, wire mills, foundries, powder plants and other industries. Source: CDA, Table 3.
21.	QPR*	Total production of refined copper from Primary Sources. Source: Copper Development Association (CDA), Table 1, item 13. Series is adjusted to include refined copper produced from scrap and sold at the primary producers price and to exclude copper produced from ore yet sold in the secondary market.
22.	QR = QSR + QPR*	Total production of refined copper in the U.S. in 1,000 short tons. Source: CDA, Table 1.
23.	QSNR*	Receipts of domestic scrap that are not sent to secondary smelters and refiners. Source: CDA (QS-QSR).
24.	QSR*	Production of refined copper in the United States produced from scrap. Source: CDA, Table 1, item 13. Series is adjusted to include copper produced from ore and sold in the outside market and to exclude copper produced from scrap and sold at the primary producers' price.
25.	RPEMJ*	Deflated PEMJ. Deflator is alternatively PUWD or PUWD74.
26.	RPFUT1*	PFUT1 deflated by PUWD or PUWD74.
27.	RPS*	The real price of scrap, PS, deflated by PUWD or PUWD74.

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28.	RPSR*	A recorded price series for secondary refined copper is not available in the literature. Our series has been built up using the price of scrap, PS, and the margins characterizing the secondary sector over the historical period, SPRED: PSR = PS + SPRED. RPSR is the real secondary price, deflated by PUWD or PUWD74.
29.	SPRED	Average difference between the scrap price (PS) and the price of secondary refined copper (PSR) reflecting commercial costs, operating costs and gross profits. (Arthur D. Little, Inc. estimates).

EXOGENOUS AND PREDETERMINED VARIABLES

1.	ACRO*	Relative activity variable determining net exports of copper. It is defined as the ratio of indices of manufacturing production in the U.S. and the Federal Republic of Germany (ACRO = YUD/YGR). Alternative ratios have been investigated involving the indices of manufacturing production in Japan, France, the U.K., EEC and the OECD.
2.	DSTE2*	Dummy variable indicating whether a strike is expected next year and how many months it is expected to last. For example, if a 2-1/2 month strike is expected to affect between 75-100% of production next year, DSTE2 = 2.5. DSTE2 = 0 if no strike is espected. (DSTE2(t) = DUMST2(T+1)).

3.	DUMST2*	Dummy variable for strikes affecting the smelting and refining stages of copper production. Dummy estimates number of months a major strike affected more than 75% of the production workers in the industry; 0.0 when no strike. Source: Interviews with Asarco, Phelps Dodge, Kennecott and Anaconda.
4.	IGOV*	Refined copper stocks held in government stockpile, end of year. Source: CDA, Table 1, item 16. $\Delta IGOV = IGOV(t) - IGOV(t-1) = DIGOV$
5.	KAPP*	KAPPR + KAPSR
6.	KAPPR*	Copper refining capacity of the primary producers beginning of the year in 1,000 short-tons per year. Source: ABMS Yearbook. KAPPR is endogenous in the investment module.
7.	KAPSR*	Copper refinery capacity, secondary producers at beginning of year in 1,000 short-tons per year. Both primary and secondary capacity definitions are aimed at estimating capacity utilized for producing copper for sale at the primary producers' price or the outside market price. Capacity in the secondary market has therefore been that of AMAX and Cerro, since production of the two companies has been predominantly sold at competitive outside market prices.
8.	PAUSC	Scrap aluminum clipping prices, monthly averages of dealers' buying prices of new aluminum clippings in New York, American Metal Market, ¢/lb.

9.	PLME	The London Metals Exchange Price of Copper: electrolytic, delivered for 1946 to 1953; electrolytic wire bars monthly average settlement price for 1953 to 1974. Asked quotation for spot is converted to ¢/lb by the annual average exchange rate for sterling. Both series found in ABMS Yearbook--"Average Prices of Principal Metals," (p. 147 in the 1973 Yearbook).
10.	QFAB*	Supply of mill, foundry and power products to domestic market-total. Source: CDA, Table 4.
11.	RPAL*	Deflated price of scrap aluminum clippings (PAUSC deflated by PUWD or PUWD74) in ¢/lb.
12.	RPLME*	Deflated LME price of copper (PLME deflated by PUWD or PUWD74) in ¢/lb.
13.	VARCOS*	Unit average variable cost of operating cost of the primary producers.
14.	YGR	Index of manufacturing production, Federal Republic of West Germany, 1963 base year converted to 1974 = 100. Source: IMF, International Financial Statistics, Washington.
15.	YUD	Federal Reserve Board Index of Durable Manufacturers Production, 1967 base year converted to 1974 = 100.

INVESTMENT MODULE
ENDOGENOUS VARIABLES

No.		
1.	QCU*	The supply primary copper in the United States from mine production. Source: CDA, Table 1.
2.	NETY*	Net income, the calculation of earnings after deductions for costs and taxes, often called earnings to surplus. The seven companies included in the compilation of net income are: Phelps Dodge, Kennecott, Anaconda, AMAX, Asarco, Inspiration, Consolidated Copper and Copper Range. Source: Moody's.

EXOGENOUS AND PREDETERMINED VARIABLES

1.	CCAP*	Weighted average cost of debt and equity capital to the primary producers, the weights being the levels of debt and equity capitalzation. Many alternative definitions of this cost of capital are possible. The alternatives developed for our analysis are discussed fully in Appendix F.
2.	DGNP74	Implicit deflator of GNP for the U.S. converted to 1974 base year from 1958 base year. Source: U.S. Department of Commerce, Survey of Current Business.
3.	PDGNP	Implicit price deflator, gross national product. Source: Department of Commerce, Bureau of Economic Analysis. 1972 = 100, updated to 1974 = 100.
4.	PDPDE	Implicit price deflator, fixed investment, non-residential producers' durable equipment. Source: Department of Commerce, Bureau of Economic Analysis. 1972 = 100, updated to 1974 = 100.
5.	PUWD74	Wholesale price index of durable manufacturing, 1974 = 100. Source: BLS.

6.	KAPP* _	KAPPR + KAPSR
7.	KAPPR*	Copper refining capacity of the primary producers beginning of the year in 1,000 short-tons per year. Source: ABMS Yearbook. KAPPR is endogenous in the investment module.
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